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RESEARCH IN HUMAN GROWTH

1.

RESEARCH in human growth has attained a considerable age, and with it some degree of maturity. Today, nearly 200 years after the first longitudinal growth study (Scammon, '27) we are still acquiring a basic knowledge of the mechanisms and processes of growth in man.

Growth in general is not well understood.[1] Though easy to measure, and simple to demonstrate, why things grow is still a fundamental mystery. Little is known about growth at the cell level, still less about the nature of multi-cellular growth. More complicated aspects of growth spill over into the problem of form (Bonner, '52). The growth of a leaf is an analytic puzzle of itself; still more the growth of the morphologically simpler but structurally more complex fish (Thompson, '42). And with mammals, with vastly different growth rates for individual organs and tissues and with numerous growth-limiting systems, we need to investigate one process or one mechanism at a time, if we are to elucidate the nature of growth.

[1] Count ('55) has called growth a "catchall" term. While many different processes modify or affect growth it is still possible to center attention on the phenomenon of growth itself.

We know most about statural growth in man. It is admittedly a summation, and admittedly a special kind of growth, not quite an example of Scammon's "general" growth curve. But stature (or crown-heel length, or recumbent length) is simple to measure, and can be followed in the same subject from birth onward. By measuring from the sole of the foot to vertex, a whole range of phenomena have been discovered. Some are characteristic of all mammals, some are characteristic of man, while others are reflections of changes in the way of life, in nutritional knowledge, or in the management of "childhood" diseases.

We know far less about the growth of the body segments. Though segmental growth rates have been published for some populations (Kelly and Reynolds, '47, Meredith, '47, Anderson *et al.*, '56) the role of the long bones in the trend toward increasing stature is still unclear. We know rather little about the true growth of the skull and its components. Should we consider the bone or the suture? (*cf.* Baer, '54, Mednick and Washburn, '56). The face itself provides a particular problem, for it cannot be fragmented into growing components by conventional cephalometry. Tooth development, on the other hand, proves far more accessible to radiological investigation (Gleiser and Hunt, '55, Garn, Lewis and Shoemaker, '56) as does the ossification of the spine. The growth of individual muscle groups, known at present by dissection of laboratory material, is not beyond the scope of serial roentgenographic studies, and with the judicious use of contrast techniques, semi-longitudinal analysis of the growth of particular inner organs may prove practical.

Endocrine knowledge has reached the point where most students of growth speak knowingly of the growth-promoting and thyroid-stimulating pituitary hormones, of the protein anabolic hormones, and the cortical-stimulating hormones. Though they may not measure the neutral ketonic steroids, they are aware of their influences on the epiphysial plate. Moreover, measurements of the 17-ketosteroids is no longer a novelty. From testosterone administration, to monkeys (Van Wagenen and Hurme, '50), to developmentally retarded children (Sobel, *et al.*, '56), and to starvation victims, the influence of such steroids is becoming clear. The experimental approach may be impractical in most growth studies, but the research design can be organized so that hormonal effects can be brought into consideration (Talmers, '52).

Students of animal heredity have contributed magnificently to the genetics of growth. With the very practical purpose of selecting for meat, for rapid growth, or for convenient barnyard proportions, both their techniques and their findings bear closest watching (Hancock, '51,

Barnicoat and Shoreland, '52, Shoreland *et al.*, '47). The question of parental size and its influence on the offspring, recalls Galton's investigations published in 1889, and his statistical device the "mid-parent." Selection for maximum muscle mass, a technique important to New Zealand sheep-raisers, suggests a kind of study that can be applied to selected matings in man. And techniques developed for the study of human physical growth have been taken over by geneticists specializing in hogs, cattle and sheep. Thus, when genes that control fattening, fleshing or axial growth are discovered for our domestic animals (*cf.* Dickerson, '54), the possibility of uncovering similar phenomena in human beings, through the use of the same techniques, looms near.

2.

The progress of most areas in science can be estimated first by counting journal articles, and then by enumerating textbooks. By this rule, human growth is growing right along. Though publications are dispersed among the medical, physiological and anthropological literature, the sum total has increased to the point where no yearly review can do justice to them all. We are as likely to find a "growth" article in the *Journal of Applied Physiology* as in *Growth*, in *Child Development* as in *Human Biology*, in the *Journal of Social and Preventive Medicine*, as in the *American Journal of Physical Anthropology*. And the number of general texts has increased impressively since "Growth" (Robbins *et al.*, '28) and "The Measurement of Man" (Harris *et al.*, '30). It is unfortunate that American readers do not have an opportunity to peruse De Toni's "L'accrescimento Umano" ('54), and Suarez' "Crecimiento" ('54), as they do Tanner's splendid "Growth at Adolescence" ('56).

Another rule for judging the progress of a science, is to enumerate those institutions where research is carried on, not just because of a lone investigator's interest, but because the particular area has become recognized. In this country we have at least 5 permanent, well established centers: Merrill-Palmer, Iowa Child Welfare Station, Denver Child Research, The Harvard Study, and the Fels (*cf.* Tanner, '48). Besides these, there are active studies at the Forsyth Dental Infirmary, the University of Oregon, the University of Louisville School of Medicine, and the new and important Philadelphia Study for Research in Child Growth. And abroad, a very large number of studies have been inaugurated—in London, Oxford, Paris, Brussels, and Helsinki. Nutritional studies at Iowa are paralleled by nutritional studies in Mel-

bourne; major research is carried on in Guatemala, Uganda, and Capetown, while publications pour in from Japan, New Zealand, Holland, Italy and (in a torrent) from the busy Scandinavian countries.

Still another test is that of financial support. This is not an "exact" test, because research relating to children appeals to governments. Moreover, research grants often follow fashion. Devise a growth investigation that employs tranquilizers, and obtain funds by return mail! Yet, there are over two-dozen government and non-government agencies in the United States that stand ready to entertain applications in the field of human growth. These may be entered under the following categories: (1) Child Development, (2) Mental Health, (3) Maternal and Child Health, (4) Nutrition, (5) Radiation, (6) Dental Health, (7) Human Genetics, (8) Disaster Research, (9) Morale Studies, (10) Cancer Research, (11) Mental Deficiency and (12) Biometrics. To qualified applicants, funds are now available for laboratory construction, building, training of personnel, and education. Besides government, and the major philanthropies, growth research has been supported by fraternal orders, civic duty clubs, women's organizations, religious groups, and state affilliates of the large medical funds.

And finally, in evaluating the present status of growth research, consider where human growth is taught. It is not in the medical schools, where a meagre fraction of the lectures on Pediatrics are devoted to the elements of growth,[2] nor in those few colleges where "human growth" is offered as a part of biology, but in the departments of Psychology, Education and Child Development, that the most attention is currently given to the phenomenon of growth in man. Education majors are often given more information on growth (some of it inaccurate) than anthropology majors or biology concentrators. The growing field of Child Development, replacing Home Economics on many campuses, usually includes a course on "growth": the new area of Family Studies makes growth and development a major part. And to fill the need for teachers, some graduate schools of education grant a Ph. D. or Ed. D. degree in *Growth*, a degree that has premium value as state-supported schools of education expand.

[2] The medical schools feel that growth is adequately presented in first-year anatomy, and in lectures on pediatrics. This claim may be viewed with doubt.

3.

Today's studies in human growth tend to differ from those of yesteryear in being increasingly problem-oriented, theory-conscious, and biologically relevant. The purely normative, purely applied study, is being taken over by the medical profession, as is entirely proper. The purely descriptive study, while still here, tends to be so much more conscious of theory and mechanisms as to have an entirely different flavor. And while height and weight are still included in growth studies, these two are increasingly employed as reference standards, rather than as prime variables.

At the same time, studies in human growth are subjected to constant reappraisals both from within and without. The emphasis is less on "how to" and more on "why." Ten years ago the program at the Fels Research Institute was appraised by an advisory board, selected for that particular purpose. More recently the studies at the Denever Child Research Council were evaluated and within the past year a team from the University of Pittsburgh studied longitudinal studies and appraised them (Kodlin and Thompson, '56). These appraisals and evaluations, coupled with Tanner's earlier admonitions (Tanner, '51, '52) have brought a "new look," a new approach to strategy, a commendable degree of self-criticism. Why collect growth data against some indefinite date in the future? Why use the longitudinal approach for problems essentially cross-sectional? Why pursue a problem when that problem no longer continues to exist? [3]

As a result it would appear that there has been a healthy shift of attention from the approach to the problem. The very approach of the conventional longitudinal study (with its emphasis on well-off, healthy children) resulted in ignoring some very real problems of growth. The under-privileged child can contribute information on growth, so can the victim of strife or pestilence. World events, in recent years, have brought about a host of "natural experiments." In the siege of Leningrad (Antonov, '47) and the terrible winter in Rotterdam (Smith, '47), the effect of maternal undernutrition has become evident. The capture and relocation of civilian populations has contributed important infor-

[3] Both Sontag ('55), and A. L. Washburn ('56) have commented on the optimistic "shotgun" approach that characterized the early days of longitudinal studies (*cf.* Kodlin and Thompson, '56). Sontag, in particular, calls attention to the fact that problems change too. What is a burning problem of today, may appear passé a decade hence.

mation for growth research (*cf.* Garn and Moorrees, '52). And the changes in diet that followed the German occupation of Scandinavia, not only posed a major investigative problem, but the findings on dental health (Toverud, '56) may prove more revealing than a decade of lactobaccilus counts and Stannous fluoride experiments on well-to-do Americans in Eugene, Oregon, or Trenton, New Jersey.

4.

Inevitably, growth studies have become more technological. Where once a yardstick and a beam-scale constituted the sum total of equipment, a vastly greater inventory of tools and techniques seems necessary today. No one study can afford all of them, or even an appreciable fraction of them. This constitutes an advantage in itself, a guarantee against sameness, the "me too" approach to research. Before purchasing a direct-writing electrocardiograph, an electromyelograph, or a recording dermal thermometer, the research worker needs to consider his overall plan and the relevance of the instruments to the purposes of his research.

Our knowledge of growth in the living has been furthered much by radiography. Bone lengths, muscle size, fat thickness, heart size, dental formation, the growth of the cranium—all of these are best investigated through the medium of the x-ray film. And the possibilities of radiology have barely been explored. Tomography ,by way of example, has rarely been used in growth studies, and Paatero's new system of pantomography (Paatero, '54) would seem to open new avenues for research. Since the high tension side of an x-ray unit can be triggered by a low-voltage signal, it is possible to "freeze" the heart, or a muscle complex in action. And by metallic staining, radiography can now overlap with histology (O'Rahilly and Meyer, '56).

There is growing awareness of radiation hazards, and the long-term consequences of radiation far below the lethal dose (*cf.* Miller, '56). Inevitably, this awareness will limit the extent of radiation used in growth studies. But it need not preclude the intelligent use of radiography: "shotgun" research has no basis for existing, there is no need to try x-rays of this and x-rays of that. There is no need to use more penetrating radiation than is absolutely necessary. "No-screen" film (sometimes used in taking carpal x-rays) requires *ten times more exposure* than does fast film with intensifying screens. New "lightening" screens can halve the total exposure again. Forced development yields

an increased density on the film, thus allowing a still lower exposure to x-radiation. Besides, more attention can be given to shielding. Why expose most of the body, to obtain a radiograph of a limb, when an adjustable "Videx" or Phillips cone can limit radiation to the exact area required? Why encounter even the very low risk of mutations, when a simple lead-rubber shield can limit gonadal radiation to 0.02 R or less for an entire series of soft-tissue radiographs?

Interestingly, effective use of photography has rarely been made in growth studies. While photographs have been taken and published as examples of this or that, the fact that photography is a powerful tool, has been lost to sight, except perhaps to the followers of Sheldon. Yet, as Gavan, Washburn and Lewis ('52) demonstrated, a photograph can serve as substitute for the subject. Photographic anthropometry is quite practical with ordinary equipment or the "Photometric" camera. Photographs can yield measurements of small details, and can afford quantitative data on sexual maturation (*cf.* Garn, '52). Surface area can be determined by planimetry of shadowgrams or specially-posed photographs, as Benedict showed forty years ago, and Geoghegan ('53) more recently. And for the study of the superficial blood vessels, infra-red photographs are better than the subjects, as the illustrations published by Abramson and Glazier ('56) clearly show.

While we may pride ourselves in going "beneath the surface" with skinfold calipers and deep radiography, there is still much to be learned from purely superficial studies. The pigments of living human skin bear considerable investigation (*cf.* Lasker, '54); they undergo profound changes during sexual maturation (Garn, Selby and Crawford, '56). Besides, the sebaceous secretions of the skin, the activity of apocrine and holocrine glands, and the behavior of labelled hair follicles remain to be studied throughout the life span.

5.

I have left until last mathematical and graphical analyses of growth in man. No one can doubt the potential contribution of mathematical analyses to the understanding of growth. At the same time, there is no great discovery in proving that a curve can be fitted, nor in demonstrating that some transform effectively straightens a curvilinear relationship. Such work constitutes a necessary prerequisite for further studies and is not an end-point of itself.

Moreover, there is a positive danger in generalizing from curves.

The "curve of population growth" works for man in the mass, but applies to not one individual child. Robertson argued that the "adolescent spurt" was an inevitable characteristic of an autocatylitic monomolecular reaction: today we know the hormonal basis of this very spurt. The log/log plot appears to fit a variety of length/length data, but the same data often follow a straight line on simple linear coordinates.

Curves, curve-fitting, points of inflection and differences in the value of k are meaningful when they are related to biology, or when they bear upon or suggest new biological mechanisms. Huxley's hypothetical Martian, given age-size data for individual human beings, would correctly infer some important change occurring shortly after the first decade, and a second change sometime in the second decade. That selfsame erudite Martian, would correctly infer (from the shifting value of k) that the growth of the human embryo changes abruptly at the end of the first trimester. Both facts would be new to the Martian: they are not new to us!

This observation applies to many of the mathematical analyses of growth that can be found in the literature today. It is not that the logistic curve, or Courtis "personalized" double-log cycles, or neo-Huxleyan allometry are wrong, it is that the applications are rarely rooted in biology, and still more rarely relate to the biology of growth.

6.

What to say about research in human growth? I have tried twice, once by myself (Garn, '56b) and once with company (Sontag and Garn, '54), to review a part of the literature. Krogman's recent compendium (Krogman, '56), absolves me from part of that task now. I have attempted here to indicate some of the less obvious things about human growth studies, to highlight some of today's work and to suggest some of tomorrow's findings.

The measurement of human growth has not changed radically since "The Measurement of Man" (Harris *et al.*, '30), and "Growth" (Robbins *et al.*, '28). Even with tricoordinate anthropometry, the photometric camera, and teleoroentgenogrammetry—a horrid word—our knowledge of the growth phenomenon is not notably different from what Scammon knew.

I cannot discern the existence of a New Human Growth, a developmental twin to Washburn's "New Physical Anthropology." Today's most intriguing problems in growth are contemporary with Montbeillard,

Buffon and Galton, Hrdlička, Todd and Scammon. We still want to know why we grow, and why we grow as we do grow.

I have been fortunate in having had a chance to investigate phenomena accessible only through biochemistry, roentgenology, or spectrophotometry. Yet the serum lipids, the development of the permanent molars, or the pigments of living human skin do not contribute to the knowledge of growth unless they indicate how we grow, why we grow, how size and form are attained, or how any of these can be modified. The problem of growth remains the foremost problem in research relating to growth. To coin a cliche, the proper study of growth research is growth.

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GROWTH OF SOUTH AFRICAN BABIES IN THE FIRST YEAR OF LIFE [1]

BY EVA J. SALBER [2]

This paper is a report of growth of European, Colored, Bantu and Indian babies in the first year of life, as measured by their weights from two to 52 weeks.

MATERIAL USED AND METHOD OF ANALYSIS

This is a mixed longitudinal and cross-sectional study, since—although the same babies are followed over a year,—not all the babies attended every week, and the sample and number of babies at each week therefore varies.

Data were extracted from the records of:

2096	European infants:	1116 boys,	980 girls.
1303	Bantu infants:	628 boys,	675 girls.
579	Colored infants:	284 boys,	295 girls.
509	Indian infants:	259 boys,	250 girls.

All available records from the Durban Municipal Child Welfare Clinics from 1948—1951 were used, but multiple births and records of infants who had attended less than 6 times in their first year were excluded. The data extracted consisted of race, sex, birth rank, birth weight where available, dates of attendance and weights at those attendances from two to 52 weeks. Since in the non-European groups the birth weight was often not recorded and a certain number of premature babies must inadvertently have been included in the records used, premature babies in the European group were deliberately included so as to make the records comparable.

[1] This paper forms part of the material of an M. D. thesis, University of Cape Town.

[2] Formerly of Department of Medicine, University of Cape Town and of the Institute of Family and Community Health, Durban.

In the first instance, the growth curves and rates of growth were compared in the four racial groups, for boys and girls separately. Mean weights and standard deviations were worked out for each week from two to 52 weeks. The figures were then smoothed by taking a running average over 5 weeks, for example the 8 week figure was an average of the mean weights at 6, 7, 8, 9 and 10 weeks. At each end of the scale (2–3 and 51–52 weeks) this was not possible, so the third week weight and the 51st week weight were calculated on an average of three weeks only (2, 3, 4 and 50, 51, 52) while the second week and the 52nd week showed the actual weights for that week only. These figures were used for the graphs and also for calculating increments of growth.

The rates of growth of the babies of the four racial groups were calculated at four week intervals during the first year, by successive substraction of mean weights at those age levels, and this was expressed also as the number of ounces gained per week.

RESULTS

Tables 1–4 show the mean weights from two to 52 weeks for each racial group, boys and girls separately. First born (rank 1) and subsequently born (rank 2 +) and combined. Charts 1(a) and (b) are a comparison of the growth curves of European, Colored, Bantu and Indian babies during the first year of life, for boys and girls separately, all ranks combined and irrespective of birth weights.

Boys

(1) At the beginning of the year European babies are the heaviest, Indian babies the lightest, and the Colored and Bantu babies occupy an intermediate position with the Colored slightly higher than the Bantu. At the end of the year, the European babies are still the heaviest and the Indian the lightest, but the Colored and Bantu, although still occupying an intermediate position have reversed their places, the Bantu now being heavier than the Colored.

(2) At three weeks the European and Colored weights are the same, 8.40 lbs and 8.42 lbs, while the Bantu are slightly less at 8.22 lbs and the Indian about a pound lower at 7.33 lbs. At 51 weeks the gap has widened considerably with Europeans 22.53 lbs and the difference between European and Bantu being 1.59 lbs. European and Colored 2.17 lbs, and European and Indian 4.28 lbs. Fifty-one weeks has been chosen rather that 52 weeks because of a peculiar spurt shown by the Bantu and

TABLE 1

Weights of European infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2	7.85	7.25	8.06	7.74	7.98	7.55
3(2–4)	8.23	7.77	8.51	8.17	8.40	8.01
4(2–6)	8.66	8.22	8.96	8.58	8.83	8.43
5(3–7)	9.08	8.65	9.39	8.99	9.26	8.84
6(4–8)	9.50	9.08	9.81	9.40	9.68	9.26
7(5–9)	9.92	9.49	10.24	9.76	10.10	9.64
8(6–10)	10.34	9.88	10.63	10.11	10.50	10.01
9(7–11)	10.74	10.26	11.05	10.47	10.91	10.37
10(8–12)	11.12	10.65	11.45	10.85	11.30	10.76
11(9–13)	11.53	10.99	11.82	11.18	11.69	11.09
12(10–14)	11.94	11.36	12.22	11.55	12.09	11.46
13(11–15)	12.36	11.71	12.59	11.92	12.49	11.83
14(12–16)	12.75	12.05	12.97	12.28	12.87	12.17
15(13–17)	13.16	12.40	13.36	12.60	13.27	12.51
16(14–18)	13.56	12.77	13.75	12.94	13.66	12.86
17(15–19)	13.92	13.11	14.12	13.26	14.02	13.19
18(16–20)	14.26	13.46	14.48	13.56	14.38	13.51
19(17–21)	14.62	13.81	14.83	13.86	14.73	13.84
20(18–22)	14.97	14.13	15.18	14.15	15.08	14.14
21(19–23)	15.26	14.45	15.51	14.45	15.39	14.45
22(20–24)	15.61	14.78	15.79	14.69	15.70	14.73
23(21–25)	15.90	15.07	16.10	14.98	16.00	15.02
24(22–26)	16.22	15.38	16.40	15.26	16.31	15.32
25(23–27)	16.49	15.66	16.69	15.50	16.59	15.58
26(24–28)	16.79	15.94	16.97	15.76	16.88	15.85
27(25–29)	17.03	16.17	17.29	16.10	17.17	16.14
28(26–30)	17.33	16.47	17.55	16.35	17.45	16.41
29(27–31)	17.59	16.73	17.80	16.57	17.70	16.65
30(28–32)	17.88	17.00	18.07	16.82	17.99	16.91
31(29–33)	18.14	17.25	18.31	17.07	18.24	17.16
32(30–34)	18.43	17.51	18.52	17.25	18.48	17.38
33(31–35)	18.65	17.70	18.80	17.46	18.73	17.58
34(32–36)	18.86	17.93	19.02	17.72	18.95	17.82
35(33–37)	19.09	18.21	19.25	17.97	19.17	18.08
36(34–38)	19.32	18.46	19.48	18.21	19.40	18.33
37(35–39)	19.54	18.70	19.74	18.44	19.65	18.57
38(36–40)	19.77	18.95	19.92	18.72	19.85	18.84
39(37–41)	20.05	19.19	20.20	18.94	20.13	19.07
40(38–42)	20.27	19.40	20.37	19.07	20.32	19.24
41(39–43)	20.51	19.59	20.56	19.30	20.54	19.44
42(40–44)	20.73	19.76	20.68	19.44	20.70	19.60
43(41–45)	20.99	19.97	20.93	19.58	20.96	19.78
44(42–46)	21.19	20.14	21.05	19.66	21.12	19.90
45(43–47)	21.44	20.32	21.16	19.90	21.29	20.10
46(44–48)	21.61	20.45	21.35	19.98	21.47	20.21
47(45–49)	21.89	20.66	21.53	20.19	21.70	20.41
48(46–50)	22.12	20.82	21.65	20.30	21.86	20.55
49(47–51)	22.37	21.03	21.85	20.50	22.09	20.76
50(48–52)	22.56	21.22	22.09	20.71	22.30	20.96
51(50–52)	22.80	21.48	22.31	20.88	22.53	21.17
52	22.94	21.72	22.47	21.34	22.67	21.52

TABLE 2

Weights of Colored infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2			7.99	7.96	7.89	7.76
3(2–4)	7.90	7.56	8.58	8.19	8.42	8.02
4(2–6)	8.42	8.10	9.10	8.57	8.90	8.43
5(3–7)	8.85	8.56	9.60	8.93	9.38	8.81
6(4–8)	9.32	9.01	10.07	9.33	9.84	9.22
7(5–9)	9.75	9.40	10.52	9.76	10.29	9.64
8(6–10)	10.22	9.78	10.94	10.15	10.72	10.03
9(7–11)	10.70	10.16	11.31	10.56	11.13	10.43
10(8–12)	11.11	10.54	11.75	10.91	11.56	10.79
11(9–13)	11.45	10.90	12.11	11.22	11.92	11.12
12(10–14)	11.79	11.29	12.46	11.51	12.28	11.44
13(11–15)	12.13	11.56	12.83	11.80	12.63	11.72
14(12–16)	12.48	11.93	13.05	12.13	12.88	12.06
15(13–17)	12.84	12.21	13.24	12.34	13.12	12.30
16(14–18)	13.26	12.51	13.53	12.62	13.44	12.58
17(15–19)	13.64	12.89	13.81	12.88	13.74	12.89
18(16–20)	14.07	13.35	14.05	13.14	14.03	13.22
19(17–21)	14.37	13.59	14.52	13.42	14.46	13.47
20(18–22)	14.70	13.89	14.82	13.76	14.78	13.80
21(19–23)	15.00	14.37	15.14	14.13	15.09	14.16
22(20–24)	15.24	14.49	15.43	14.35	15.35	14.34
23(21–25)	15.36	14.63	15.74	14.52	15.61	14.49
24(22–26)	15.54	14.89	15.89	14.69	15.77	14.70
25(23–27)	15.69	15.19	16.18	14.92	16.03	14.96
26(24–28)	15.76	15.14	16.47	15.08	16.33	15.09
27(25–29)	16.00	15.42	16.68	15.28	16.54	15.37
28(26–30)		15.25	16.89	15.66	16.73	15.73
29(27–31)			17.16	15.79	17.03	15.90
30(28–32)			17.50	16.02	17.31	16.09
31(29–33)			17.63	16.00	17.41	16.20
32(30–34)			17.86	16.16	17.67	16.35
33(31–35)			18.05	16.32	17.93	16.44
34(32–36)			18.04	16.61	18.02	16.70
35(33–37)			18.16	16.63	18.17	16.80
36(34–38)			18.30	16.82	18.34	16.98
37(35–39)			18.51	17.04	18.51	17.20
38(36–40)			18.59	17.10	18.62	17.39
39(37–41)			18.88	17.04	18.81	17.47
40(38–42)			18.88	17.28	18.86	17.80
41(39–43)			19.07	17.69	18.99	18.10
42(40–44)			19.21	17.72	19.15	18.17
43(41–45)			19.20	17.90	19.12	18.29
44(42–46)			19.27	18.10	19.24	18.43
45(43–47)			19.26	18.01	19.28	18.31
46(44–48)			19.23	17.92	19.39	18.33
47(45–49)			19.29	18.14	19.47	18.50
48(46–50)			19.55	18.11	19.74	18.50
49(47–51)			19.72	18.34	19.86	18.80
50(48–52)			20.17	18.60	20.23	19.02
51(50–52)			20.41	18.77	20.36	19.21
52			21.05	18.81	20.94	19.22

TABLE 3

Weights of Bantu infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2	7.28	6.75	7.71	7.44	7.60	7.29
3(2–4)	7.83	7.44	8.34	8.05	8.22	7.90
4(2–6)	8.36	8.02	8.97	8.60	8.80	8.46
5(3–7)	8.93	8.58	9.55	9.14	9.38	9.01
6(4–8)	9.58	9.13	10.14	9.65	9.98	9.54
7(5–9)	10.18	9.67	10.71	10.12	10.55	10.03
8(6–10)	10.83	10.21	11.26	10.58	11.13	10.51
9(7–11)	11.48	10.68	11.76	11.02	11.67	10.96
10(8–12)	12.01	11.21	12.21	11.48	12.15	11.43
11(9–13)	12.46	11.58	12.67	11.88	12.60	11.82
12(10–14)	12.86	12.05	13.09	12.30	13.05	12.24
13(11–15)	13.20	12.46	13.46	12.68	13.42	12.63
14(12–16)	13.64	12.82	13.86	13.08	13.84	13.02
15(13–17)	14.03	13.08	14.17	13.38	14.17	13.31
16(14–18)	14.44	13.49	14.53	13.75	14.54	13.69
17(15–19)	14.87	13.74	14.81	14.03	14.83	13.97
18(16–20)	15.32	14.07	15.09	14.30	15.15	14.25
19(17–21)	15.63	14.27	15.34	14.50	15.42	14.46
20(18–22)	15.98	14.57	15.68	14.79	15.77	14.74
21(19–23)	16.19	14.86	15.86	15.03	15.96	15.00
22(20–24)	16.47	15.10	16.12	15.34	16.22	15.29
23(21–25)	16.58	15.33	16.37	15.61	16.43	15.55
24(22–26)	16.83	15.68	16.66	15.85	16.71	15.81
25(23–27)	17.06	15.84	16.92	16.08	16.97	16.02
26(24–28)	17.23	16.10	17.16	16.23	17.19	16.20
27(25–29)	17.39	16.25	17.41	16.37	17.42	16.34
28(26–30)	17.70	16.45	17.58	16.54	17.64	16.52
29(27–31)	17.79	16.77	17.81	16.74	17.82	16.76
30(28–32)	17.90	17.12	17.97	16.88	17.95	16.93
31(29–33)	18.31	17.26	18.14	17.05	18.19	17.10
32(30–34)	18.52	17.50	18.20	17.31	18.30	17.35
33(31–35)	18.74	17.61	18.36	17.43	18.48	17.47
34(32–36)	18.92	17.67	18.44	17.61	18.59	17.61
35(33–37)	19.10	17.78	18.59	17.66	18.75	17.69
36(34–38)	19.14	17.82	18.86	17.86	18.93	17.85
37(35–39)	19.15	17.96	19.18	17.97	19.21	17.92
38(36–40)		17.82	19.35	18.18	19.36	18.11
39(37–41)			19.62	18.35	19.60	18.27
40(38–42)			19.67	18.56	19.67	18.45
41(39–43)			19.69	18.60	19.68	18.57
42(40–44)			19.70	18.56	19.71	18.62
43(41–45)			19.82	18.50	19.79	18.57
44(42–46)			19.68	18.51	19.71	18.65
45(43–47)			19.87	18.61	19.90	18.72
46(44–48)			19.91	18.89	19.95	18.92
47(45–49)			20.08	19.14	20.16	19.17
48(46–50)			20.24	19.43	20.25	19.49
49(47–51)			20.37	19.59	20.40	19.63
50(48–52)			20.65	19.72	20.70	19.83
51(50–52)			20.88	19.68	20.94	19.87
52			21.60	19.63	21.90	19.93

TABLE 4

Weights of Indian infants (in pounds) from 2–52 weeks
(running averages)

WEEK	RANK 1		RANK 2+		ALL RANKS	
	Boys	Girls	Boys	Girls	Boys	Girls
2						
3(2–4)			7.55	6.63	7.33	6.70
4(2–6)			8.14	7.45	7.94	7.35
5(3–7)	8.18		8.56	7.87	8.39	7.77
6(4–8)	8.44		9.00	8.37	8.81	8.23
7(5–9)	8.78	7.99	9.43	8.67	9.27	8.53
8(6–10)	9.15	8.27	9.81	8.99	9.64	8.78
9(7–11)	9.56	8.71	10.14	9.32	10.00	9.11
10(8–12)	9.96	9.07	10.52	9.65	10.36	9.44
11(9–13)	10.42	9.44	10.90	9.89	10.76	9.69
12(10–14)	10.73	9.87	11.22	10.21	11.07	10.04
13(11–15)	11.04	10.23	11.48	10.55	11.35	10.38
14(12–16)	11.34	10.45	11.78	10.82	11.65	10.64
15(13–17)	11.60	10.69	12.18	11.02	12.02	10.85
16(14–18)	11.95	11.03	12.51	11.27	12.35	11.12
17(15–19)	12.32	11.12	12.82	11.45	12.69	11.27
18(16–20)	12.67	11.36	13.06	11.56	12.95	11.41
19(17–21)	13.03	11.58	13.33	11.70	13.24	11.57
20(18–22)	13.32	11.82	13.52	11.93	13.45	11.82
21(19–23)	13.55	11.96	13.73	12.19	13.67	12.05
22(20–24)	13.70	12.31	13.91	12.47	13.84	12.35
23(21–25)	13.78	12.59	14.19	12.64	14.06	12.56
24(22–26)	13.90	12.86	14.50	12.85	14.32	12.79
25(23–27)	14.23	13.04	14.65	12.98	14.52	12.91
26(24–28)	14.43	13.26	14.89	13.13	14.75	13.11
27(25–29)	14.64		15.13	13.36	14.97	13.35
28(26–30)	14.94		15.39	13.54	15.25	13.55
29(27–31)	15.26		15.48	13.79	15.40	13.77
30(28–32)	15.34		15.76	14.03	15.62	14.04
31(29–33)	15.55		15.94	14.21	15.80	14.24
32(30–34)	15.84		16.11	14.27	15.99	14.29
33(31–35)	16.06		16.13	14.51	16.08	14.52
34(32–36)			16.23	14.68	16.20	14.68
35(33–37)			16.18	14.76	16.27	14.80
36(34–38)			16.23	14.78	16.35	14.84
37(35–39)			16.21	15.06	16.44	15.14
38(36–40)			16.28	15.17	16.50	15.25
39(37–41)			16.43	15.39	16.64	15.47
40(38–42)			16.65	15.48	16.76	15.59
41(39–43)			16.63	15.60	16.79	15.71
42(40–44)			16.85	15.65	16.88	15.80
43(41–45)			17.09	15.75	17.04	15.90
44(42–46)			17.26	15.72	17.23	15.98
45(43–47)			17.45	16.01	17.41	16.20
46(44–48)			17.51	16.20	17.46	16.45
47(45–49)			17.58	16.12	17.56	16.41
48(46–50)			17.61	16.22	17.68	16.60
49(47–51)			17.41	16.40	17.75	16.70
50(48–52)			17.61	16.62	17.90	17.06
51(50–52)				17.02	18.25	17.55
52				17.66	18.71	18.54

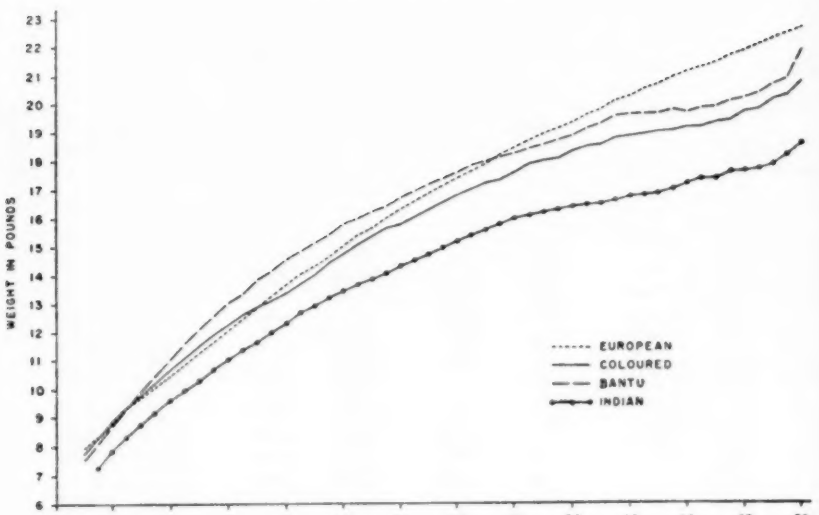

CHART 1a.

Comparison of Growth Curves of Four Racial Groups in the First Year of Life. (boys all ranks)

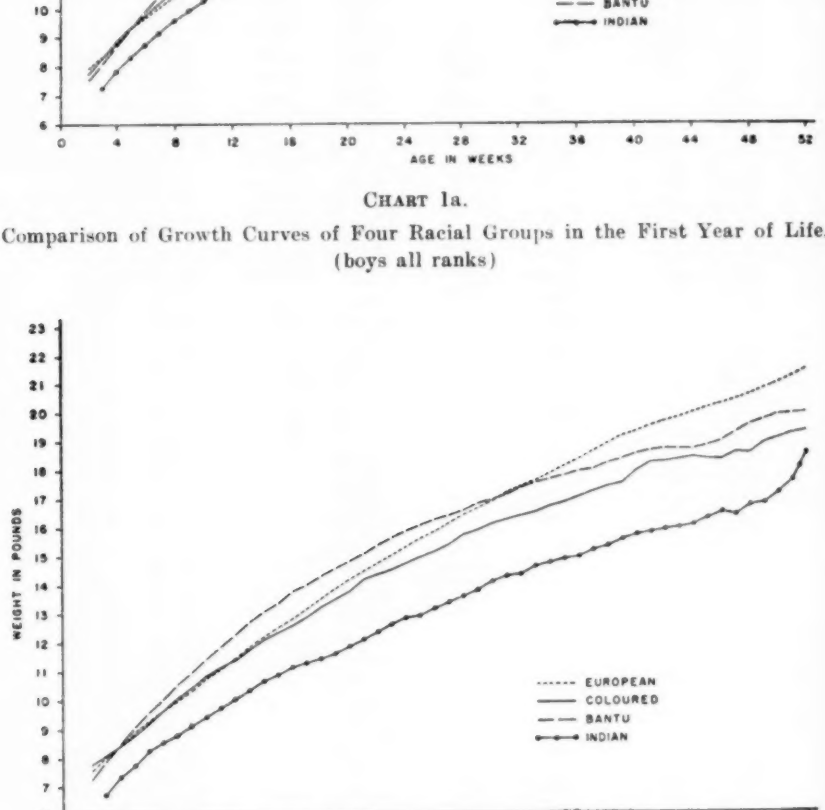

CHART 1b.

Comparison of Growth Curves of Four Racial Groups in the First Year of Life. (girls all ranks)

Colored during the last week of the year, which may be a true picture, but is probably due to the smallness of the number at this point of the graph.

(3) The Colored boys, although they start below the European, and as we know have a lower birth weight than the European, at three weeks have reached the European level and then actually rise above the European weights, although not by very much, until 14 weeks, when once again their weights drop below the European level. Thereafter there is a gradually increasing difference between these two groups for the rest of the year.

(4) In the first 8 weeks, although the Indian boys are below the European because of their lower birth weight, the European and Indian curves run parallel to each other showing the same amount of increase. The gap widens gradually from 8–32 weeks, with considerable disparity thereafter.

(5) The Bantu pattern is quite different from the European. They start below the European because of their lower birth weight, but by 5 weeks they have overtaken the European boys and remain above their level until 30 weeks. From 30 weeks there is a marked flattening of the Bantu curve and at 51 weeks the difference between European and Bantu babies is 1.59 lbs.

Girls

(1) As with boys, at the beginning of the year European girls are the heaviest, Indians the lightest and Colored and Bantu occupy an intermediate position with the Colored slightly higher than the Bantu. At the end of the year, again, the Europeans are still the heaviest and the Indians the lightest but the Bantu are heavier than the Colored.

(2) At three weeks of age European and Colored weights are the same, 8.01 lbs and 8.02 lbs, Bantu slightly less at 7.96 lbs and Indians considerably less at 6.70 lbs. At 51 weeks the European weight has reached 21.17 lbs and the difference between European and Bantu is 1.30 lbs, between European and Colored 1.96 lbs and between European and Indian 3.62 lbs.

(3) Colored girls start off slightly heavier than European girls at two weeks of age, but from three to 12 weeks there is very little difference between them. After that the pattern is the same as that shown by the boys.

(4) The curve of the Indian girls runs parallel to that of the

European girls for the first 6 weeks only (boys 8 weeks) and after that the pattern is similar to that displayed by the boys.

(5) Bantu girls overtake European girls by four weeks and follow the same pattern as the boys, but the curve does not flatten as much and the difference at 51 weeks is 1.3 lbs (not as great a difference as the boys).

COMPARISON OF RATE OF GAIN (INCREMENTS)

Boys, all ranks (See Table 5a).

TABLE 5a

½-week increments of weight (smoothed)
boys—all ranks

	EUROPEAN		COLORED		BANTU		INDIAN	
	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week
Birth weight	7.48		—		—		—	
weeks								
0– 2	.50	4.0	—		—		—	
2– 4	.85	6.8	1.01	8.1	1.20	9.6	.85 *	6.8
4– 8	1.67	6.7	1.82	7.3	2.33	9.3	1.70	6.8
8–12	1.59	6.4	1.56	6.2	1.92	7.7	1.43	5.7
12–16	1.57	6.3	1.16	4.6	1.49	6.0	1.28	5.1
16–20	1.42	5.7	1.34	5.4	1.23	4.9	1.10	4.4
20–24	1.23	4.9	.99	4.0	.94	3.8	.87	3.5
24–28	1.14	4.6	.96	3.8	.93	3.7	.93	3.7
28–32	1.03	4.1	.94	3.8	.66	2.6	.74	3.0
32–36	.92	3.7	.67	2.7	.63	2.5	.36	1.4
36–40	.92	3.7	.52	2.1	.74	3.0	.41	1.6
40–44	.80	3.2	.38	1.5	.04	.2	.47	1.9
44–48	.74	3.0	.50	2.0	.54	2.2	.45	1.8
48–52	.81	3.2	1.20	4.8	1.65	6.6	1.03	4.1
48–50	.44	3.5	.49	3.9	.45	3.6	.22	1.7
Total 2–52	14.69		13.05		14.30		11.62	
" 2–50	14.32		12.35		13.10		10.81	

* Assuming the gain per week from 2–4 weeks to be at least as great as that from 4–8 weeks.

(1) *Europeans.* From two to 20 weeks rate of growth is most rapid varying between almost 6 ozs to almost 7 ozs per week. From 20 to 32 weeks growth is not as rapid—4 to 5 ozs per week. After that until the end of the year it is between 3 and 4 ozs per week with a total gain of 14.69 lbs from 2 to 52 weeks.

(2) *Colored.* From two to 12 weeks colored babies show their most rapid period of growth—6 to 8 ozs per week, and during the first 6 weeks

their rate of growth is even greater than that of Europeans. From 12 to 32 weeks rate of growth decreases and varies between 3 to 5 ozs per week. After that there is a fairly sharp decrease—to between 1½ and 3 ozs per week. The last four-week period shows an average increase of 4.8 ozs per week, but owing to the smallness of the numbers at this end of the scale, this is not considered a reliable figure. The total gain from two to 52 weeks is 13.05 lbs.

(3) *Bantu.* From two to 8 weeks Bantu rate of growth is the most rapid of all the racial groups being over 9 ozs per week. From 8 to 16 weeks growth is still very rapid, between 6 and 8 ozs per week. From 16 to 28 weeks rate of gain is 3½ to 5 ozs per week, and from 28 to 52 weeks it is only about 2½ ozs per week. Again the figure for the last four-week period is probably not reliable. The total gain from two to 52 weeks is 14.30 lbs.

(4) *Indians.* As there is no weight at two weeks for Indian babies owing to insufficient data, the information only starts from four weeks of age. From four to 16 weeks Indian babies grow most rapidly and gain from 5 to 7 ozs per week. From 16 to 30 weeks rate of gain has slowed and is 3 to 4½ ozs per week. Thereafter their growth is very slow—from 1½ to 2 ozs per week. Again the last four-week figure is probably unreliable. Assuming the gain per week from two or four weeks to be not less than the weekly gain from four to 8 weeks, total gain from two to 52 weeks would be 11.62 lbs approximately.

From the foregoing we see that from two to 8 weeks European boys gain the least weight of the four racial groups, with the Bantu gaining the most weight, followed by the Colored, and then by the Indian. From 8 to 12 weeks the Bantu are still gaining more than the European boys, but from 12 weeks onwards to European boys gain more than any other group. In the non-European groups the Bantu gain most weight from two to 16 weeks, more than either the Colored or the Indian. After 16 weeks, however, in spite of certain slight irregularities, Colored boys gain more than either Bantu or Indian boys. But because of the tremendous amount of weight that Bantu boys have gained in the first 16 weeks (6.94 lbs as against 5.68 lbs for European, 5.55 lbs for Colored, 5.26 lbs for Indian) by the end of the year the Bantu weights are still above the colored and Indian groups in spite of the greater birth weight and the greater gain from 16 weeks shown by the Colored boys.

In the first 14 weeks (from two to 16 weeks) Bantu boys have gained

6.94 lbs as against only 6.16 lbs in the next 34 weeks (16 to 50 weeks). They are the only group who have actually gained more in this first period (two to 16 weeks) than during the rest of the year. This is due both to the largeness of the gain during the first period and the smallness of the gain during the second period.

Expressing the gain from 16 to 50 weeks as a percentage of the gain from two to 16 weeks, we find the following result:

European 152% Colored 122% Bantu 89% Indian 106%

Girls, all ranks (See Table 5b).

TABLE 5b

4-week increments of weight (smoothed)
girls—all ranks

	EUROPEAN		COLORED		BANTU		INDIAN	
	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week	incr. (lbs)	oz. per week
Birth weight	7.20		—		—		—	
weeks								
0– 2	.35	2.6	—		—		—	
2– 4	.88	7.0	.67	5.4	1.17	9.4	.72 *	5.7
4– 8	1.58	6.3	1.60	6.4	2.05	8.2	1.43	5.7
8–12	1.45	5.8	1.41	5.6	1.73	6.9	1.26	5.0
12–16	1.40	5.6	1.14	4.6	1.45	5.8	1.08	4.3
16–20	1.28	5.1	1.22	4.9	1.05	4.2	.70	2.8
20–24	1.18	4.7	.90	3.6	1.07	4.3	.97	3.9
24–28	1.09	4.4	1.03	4.1	.71	2.8	.76	3.0
28–32	.97	3.9	.62	2.5	.83	3.3	.74	3.0
32–36	.95	3.8	.63	2.5	.50	2.0	.55	2.2
36–40	.91	3.6	.82	3.3	.60	2.4	.75	3.0
40–44	.66	2.6	.63	2.5	.20	.8	.39	1.6
44–48	.65	2.6	.07	.3	.84	3.4	.62	2.5
48–52	.97	3.9	.72	2.9	.44	1.8	1.94	7.8
48–50	.41	3.3	.49	3.9	.34	2.7	.46	3.7
Total 2–52	13.97		11.46		12.64		11.91	
" 2–50	13.41		11.23		12.54		10.43	

* Assuming the gain per week from 2–4 weeks to be at least as great as that from 4–8 weeks.

(1) *Europeans.* Growth rate is again most rapid from two to 20 weeks—between 5 to 7 ozs per week. From 20 to 40 weeks rate of gain is less rapid—between 3½ to 5 ozs per week. From 40 weeks onwards the gain is just over 2½ ozs per week. Total gain from two to 52 weeks is 13.97 lbs.

(2) *Colored.* Colored girls have their most rapid period of growth

between two and 12 weeks—5½ to 6½ ozs per week. From 12 to 28 weeks the gain is 3½ to 5 ozs a week and from 28 weeks onwards average gain is about 2½ ozs a week. Total gain from two to 52 weeks is 11.46 lbs.

(3) *Bantu.* Rate of gain for Bantu girls is very rapid from two to 8 weeks—8 to 9½ ozs a week. From 8 to 16 weeks gain is still rapid at 5¾ to 7 ozs a week. From 16 to 24 weeks weight gain is a little over 4 ozs a week but from 24 weeks to the end of the year the gain is rather irregular and only between one to three ounces a week. Total gain from two to 52 weeks is 12.64 lbs.

(4) *Indians.* The most rapid period of growth here is from four to 16 weeks at 4 to 6 ozs a week. From 16 to 32 weeks it has become 2¾ to 4 ozs a week. From 32 weeks onwards (disregarding the 48 to 52 week figure) the gain has slowed to 1½ to 3 ozs a week. Again a two-week weight has been assumed giving a total gain from two to 52 weeks of 11.91 lbs approximately.

Summarising the above we see that the Bantu rate of gain from two to 16 weeks is greater than that shown by the other racial groups. In the four to 8 weeks period the Colored gain is also very slightly higher than that of the European, but Indian girls always gain the least of the four groups. Bantu girls have gained the greatest amount of weight as compared with the other three groups from two to 16 weeks of age, but unlike the boys, European girls from two weeks onwards gain more weight than either Colored or Indian girls. The picture is not as clear for the girls as for the boys, but from 16 weeks Colored girls gain more than either Bantu or Indian girls.

Expressing the gain from 16 to 50 weeks as a percentage of the gain from two to 16 weeks the results are:

European 152%, Colored 119%, Bantu 96%, Indian 132%.

DISCUSSION

A fair number of growth studies in infancy mainly cross-sectional or mixed cross-sectional longitudinal have been done. A few investigators show weekly weights during the first year, others monthly weights; some given figures at four-week intervals, and yet others give results at three-month intervals. Weights are sometimes shown in kilograms, sometimes in pounds and ounces, or in pounds and fractions of pounds. It is difficult, therefore, to compare all these studies with the results of the

present investigation in which the weights are shown at weekly levels in pounds and decimals of a pound. Ten American and British studies are compared with the results for white South African babies (table 6), and where results have been given in kilograms or in pounds and ounces, the figures have been converted to pounds and decimals of a pound. Where percentiles have been used, the 50th percentile, *i. e.*, the median value has been taken to compare with the means. No use was made of the results of studies given at four-week intervals, since they could not be converted to monthly figures, and where weekly figures were given the weights at 13, 26, 39 and 52 weeks were taken and expressed as 3, 6, 9 and 12 monthly weights. Figures for boys and girls are shown separately in each investigation. Most of the data are derived from child welfare clinic records, but some are selected samples of babies of good economic level receiving optimal pediatric and home care.

It can be seen that all the growth curves of the boys and girls in America and England are very similar, and the South African European figures do not differ to any extent from those of the other investigators.

The growth curves of the Colored, Bantu and Indian boys and girls however, do not folow the European pattern and deserve some detailed comment. From 2–8 weeks European boys gain the least weight of the four racial groups, but from 12 weeks onwards they gain the most, and their total gain from 2–52 weeks is 14.69 lbs as compared to 13.05 lbs for Colored, 14.30 lbs for Bantu and 11.62 lbs for Indian boys.

This picture is not as clearly seen in the girls, for European girls after two weeks of age gain more weight than either Colored or Indian girls though the Bantu girls gain more than the European for the first 16 weeks. The total gain in weight from 2–52 weeks in European girls is 13.97 lbs as compared with 11.46 lbs for Colored, 12.64 lbs for Bantu and 11.91 lbs for Indian girls.

Why do the European babies gain relatively little weight in the first 2–3 months of life when there is no doubt of their greater gain thereafter?

It is the opinion of the writer that European babies on the whole are underfed in early life when they are on the breast or given a bottle. Time and again one has seen the remark " baby overfed " when the child has gained 8 oz in a week. The mother is told to feed every four hours instead of every three or to feed for a shorter time, or to give less in the bottle. The non-European mother, on the whole ignores this advice, since in any case she usually does not have a clock and anyhow feeds " on

demand." In most cases her baby is breast fed and she worries far more about whether he gets enough milk rather than too much milk.

TABLE 6

Comparison of weights in first year of life: American, British and South African (Mean weight in lbs.)

AGE MONTHS	1	2	3	4	5	6	7	8	9	10	11
MALES											
Birth								7.5	7.6	7.63	7.48
1	8.58	9.61	9.3						8.5		
2	11.00	11.62	11.4						9.9		
3	12.76	13.31	13.4	11.89	12.16	14.34	13.05	12.6	12.1	13.06	12.49
4	14.52	14.81	15.2				14.74		13.9		
5	16.28	16.48	16.8				16.20		15.4		
6	17.60	17.86	18.0	16.10	16.77	18.67	17.46	16.7	16.8	17.5	16.88
7	18.04	19.27	19.0				18.56		18.0		
8	19.58	20.46	19.9				19.55		19.2		
9	20.46	21.45	20.7	19.35	20.34	21.70	20.47	20.0	20.2	20.75	20.13
10	20.68	22.62	21.5				21.22		20.9		
11	21.56	23.39	22.1				21.95		21.7		
12	22.00	24.11	22.8	21.46	23.13	23.82	22.59	22.2	22.4	23.13	22.67
FEMALES											
Birth								7.4	7.3	7.38	7.20
1	8.14	8.76	8.9						8.2		
2	9.68	10.63	10.9						9.4		
3	12.54	12.12	12.7	11.24	11.25	13.02	12.16	12.4	11.2	12.06	11.83
4	12.98	13.73	14.2				13.69		12.8		
5	15.62	15.22	15.6				15.09		14.2		
6	15.84	16.24	16.8	15.13	15.44	17.04	16.36	16.0	15.6	16.25	15.85
7	16.94	17.58	17.8				17.49		16.7		
8	18.04	18.55	18.8				18.49		17.6		
9	18.92	19.29	19.7	18.12	18.70	19.73	19.34	19.2	18.6	19.13	19.07
10	19.58	20.17	20.5				19.97		19.3		
11	20.68	20.97	21.2				20.53		20.0		
12	20.46	21.56	21.8	20.09	20.56	21.88	21.03	21.5	20.8	21.50	21.52

Investigations

1. Iowa Child Welfare Research Station ('31).
2. Bayley and Davis ('35).
3. Peatman and Higgons ('28).
4. Hill and Magee ('38).
5. Lewis–Fanning and Milligan ('44).
6. Simmons ('44).
7. Gore and Palmer ('49).
8. Children's Medical Center Boston ('49).
9. Norval *et al.* ('51).
10. Parfit ('51).
11. Present Investigation (White S. African).

Even the Colored mother who is to all intents and purposes a "poor European" still tends to breast feed her baby and ignore the clock,

although many Colored mothers wean their babies very early, and go to work, and non-European babies on the bottle almost invariably get too dilute a milk mixture in an attempt to make the tin of powdered milk last a little longer. It is the writer's experience, and this impression has been confirmed by many medical officers working with Indians, that Indian mothers complain of insufficient breast milk very early on. They do not wean their babies but supplement the feeds, though often inadequately. The Bantu mother, on the other hand, is a magnificent lactator, and it is the exception for her to wean the baby because of insufficient breast milk. Early weaning is far more often due to belief that her milk has been poisoned, and unless she can be persuaded to the contrary, the outlook for those babies is very bad.

Wickes ('52) quotes figures of average weight gain in the first few months of life taken from standard pediatric textbooks as 4–6 oz a week. Spock ('46) gives the most liberal figure (7–8 oz a week). In the present study figures for weight gain from 4–13 weeks are 6.5 oz per week for European boys and 6.0 oz for European girls. Wickes followed up 503 babies born at St. Bartholomew's Hospital and then singled out all infants who had temporary set-backs due to illness and feeding difficulties. This left a residual group of infants who had a "smooth passage since birth." These infants were then classified according to whether they were satisfied or not when first seen, and the 214 babies in the satisfied group were taken to be a normal collection of healthy, well-fed babies. Their rate of gain was compared with the remainder of the series. The median rate of gain of the normal infants approached 1.3 oz per day (9 oz per week). Wickes, however, considered that there was good evidence that the group still contained unrecognised underfed infants. He selected three infants whose early rate of gain exemplified the ideal to be aimed at. These babies were male, breast-fed babies who gained 16 oz per week from the second to the seventh week. Their weights at 6 months fell between 19½ and 20½ lbs and at one year they were between 25 and 26 lbs, which represented a steady gain of 3 oz per week, *i. e.*, less than one-fifth of that in the first three months. Wickes gained the impression that babies with the potentiality to gain at this optimal rate were commonly found amongst infants with feeding problems at this age. "These babies, when restricted, commonly cry and vomit. If the gain is above average, overfeeding is often suspected, if gaining normally, wind is usually diagnosed, whereas only if the gain is low is the true nature of the difficulty appreciated. Presumably many of the unsatisfied

infants would have been contented if the feeds in the early weeks had been adequate to allow for some degree of 'stoking up.'"

Wickes concludes that infant feeding practice to-day underestimates the requirements of the young baby. Underfeeding he considers to be extremely prevalent due to inadequate lactation, inappropriate formulas, ignorance of the optimal rate and curve of growth, and "a morbid fear of overfeeding in the early weeks."

Wood ('52) showed that many babies admitted to hospital for vomiting of unknown origin were underfed babies. Vining ('52) found overfeeding at the breast to be exceptionally rare, but underfeeding only too common. "Babies are not like penny-in-the-slot machines, and I feel sure we have done harm in insisting on exact quantities, exact times, and feeding by the clock."

It is interesting, in this connection, to compare the mean weights of the boys and girls attending the "private clinic" of a Durban practi-

TABLE 7

Gain in weight during first postnatal year of three selected infants

	M. P.		R. P.		P. P.	
WEEKS	Total gain	oz/wk.	Total gain	oz/wk.	Total gain	oz/wk.
4–13	4 lb 0½ oz	7.1	4 lb 1 oz	7.2	5 lb 2½ oz	9.2
13–26	5 " 3½ "	6.4	5 " 10½ "	7.0	6 " 5 "	7.8
26–39	5 " 3 "	6.4	4 " 10½ "	5.7	5 " 6½ "	6.7
39–50	2 " 7½ "	3.6	2 " 12½ "	4.0	3 " 2 "	4.5

tioner with those attending the municipal clinic. Until 14 weeks of age the private clinic children grow, if anything, less well than the municipal clinic children, showing that the same pattern of underfeeding prevailed in a better off section of the community. The effect of increased income was seen at the period of introduction of foods into the baby's diet, and was most marked towards the end of the year. (Salber '55).

As a point of interest too, the weight gains of three of the writer's children are included (table 7). Unfortunately there is no record of the weights of the first child, but his pattern was very much the same. All the children were breast-fed. M. P. (male) on an elastic four-hour schedule with night feeds, R. P. (female) and P. P. (male on "self-demand." All three showed a great potentiality for growth and all were "colicky" babies, M. P. and R. P. for 6 weeks, and P. P. for three months. Looking back at their records it seems possible that though

their early rate of gain was satisfactory according to the standards taught, and although there was sufficient milk (by test feeds) it is quite likely that they required still more milk than was given them and once solids were introduced (at about 15 lbs weight) their rate of growth was very rapid indeed.

GROWTH STUDIES IN AFRICA

Trowell ('46) stated that he had never seen anything but good results in African babies from their excessive feeding. Although the African baby started at a disadvantage, liberal breast-feeding often allowed him to catch up with the European child. However, after the age of 5 or 6 months the weight of many African babies fell far below that of the Europeans and became almost stationary. This was due to the fact that the breast milk was no longer sufficient for the baby's needs, and supplementation with cow's milk and solids was inadequate for the African baby, though adequate for the European baby.

In another study Trowell ('54) stated that during the first few months of life the rate of growth was almost the same among breast-fed infants of all races, and that no difference should be accepted on the basis of race or climate until the common causes of unsatisfactory growth had been excluded. He gave three reasons for an infant's failure to thrive:

(1) Infection.

(2) Undernutrition, *i. e.,* the infant received a diet which was correct in its proportions but reduced in amount so that it did not satisfy requirements. In Uganda this occurred in the first few months of life when breast milk had failed and diluted cow's milk had been substituted.

(3) The baby is fed a diet which, though adequate to satisfy hunger, contained too low a proportion of proteins. (Trowell considered that protein should constitute 14% of the calories).

This last cause was the explanation of most cases of failure to thrive, and was the cause of all the cases of severe kwashiorkor.

Welbourn ('54) compared the growth figures of Baganda children with those of Stuart and Stevenson ('50). The birth weights of the Baganda babies fell close to the 10th percentile of the American figures. From one to three months, however, the mean weights were close to the 50th percentile of the standard figures. At about the fifth month there

was a definite falling off in weight increase and from the ninth month onwards the mean weights were below the 10th percentile of the standard American figures. Welbourn says that " African babies start life as great eaters. For four or 5 months they stuff themselves with mothers' milk. But this does not prevent the inevitable hunger which follows when mothers' milk is no longer sufficient for their needs." She attributes their rapid early growth to their plentiful consumption of breast milk but during the second 6 months of life there is a marked decline in weight gain. During this time the American babies (whose weights she used for comparison) were having mixed feeding with a large variety of good foods, but the African children were having poor diets from the time their mothers' milk was insufficient for their needs.

Brock and Autret ('52) had the general impression that throughout Central Africa there is general retardation of growth similar to that recorded at Kampala by Welbourn.

Canivet ('47) compared the rate of growth of African babies in French Sudan with White French babies in France. The average birth weight of Sudanese infants was 400 gm less than that of French White infants, but at first the rate of growth of the Sudanese infants is more rapid, and their birth weight is doubled at 3½ months, whereas the French babies doubled their birth weight at 5 months. After four months the rate of growth of the black infants became less rapid and they did not treble their birth weight until the 14th month. This pattern was displayed by both male and female babies, first and later born. He explained the difference as partly physiological and partly due to the mode of life and feeding. Instead of well-regulated methods of breast-feeding, with introduction of fruit juices and mixed feeding with broth and vegetables between three and 6 months as was the French custom, the black infant was suckled by an under-nourished mother in completely irregular fashion, and the only complementary food given was adult food, which the mother had previously masticated.

Meyers ('51) studied the graph of the gain in weight of African children in Ituri, and ascertained that a decline in increase of weight was evident after 6 months.

MacKay and Martin ('52) investigated the dentition and physique of Bantu children of the Digo tribe at Msambweni in Kenya. They give the following weights for children under one year of age:

AGE	BOYS		GIRLS	
	Mean (lbs)	S.D. (lbs)	Mean (lbs)	S.D. (lbs)
Under 3 months	10.8	3.42	9.8	2.71
3 months	14.6	1.89	12.7	2.06
6 months	16.0	1.67	14.2	2.33
9 months	16.3	1.48	15.3	1.83
12 months	19.3	2.62	18.1	2.29

It can be seen that the weights at three months compare favorably with European and American figures, at 6 months growth has slowed down but is still quite good, but in the second 6 months growth is slow and well below white standards.

Woodrow and Robertson ('50) analysed the heights and weights of colored children in Cape Town attending the municipal welfare centres The sexes were not separated. Mean birth weight was 7 lbs 5 oz and weight at one year, 19 lbs. Their graph shows the familiar pattern of retardation of growth in the second half of the year.

Matthews ('55) on a group of 374 Yoruba infants found the rate of growth to be comparable to that of British infants, during the first 6 months. From about the sixth month onwards, however, the weight increase fell below British standards, especially during the second year of life.

STUDIES OF GROWTH IN INFANCY AMONG NON-WHITE CHILDREN OTHER THAN AFRICAN

Other investigations have also shown the rapid growth in early infancy and the marked retardation of growth in the second 6 months of the year.

Gounelle and Demarchi ('53) found that up to two months the Bagdad baby had the same mean weight as the European. This initial advantage was lost at the third month and up to the seventh month there was a small but marked difference of about 400 gram (.88 lbs) between the European and the Bagdad infant at the same age. From then on the position became worse until at 12 months the difference was 1.41 kg (3.1 lbs). They found the same results too when comparing the curves for French and Iraqi babies.

During 1948-1949 the Medical Research Council of New Zealand sent a team to Western Samoa to make a survey of certain health problems (Marples '50). The main object of the investigation was to

determine the incidence of skin diseases, but in a large number of children heights and weights were also recorded. The mean weights of Samoan infants up to 6 months were above, but those in the second 6 months of life were considerably below the New Zealand figures. Average weights at 12 months were in the lowest 20% of the New Zealand figures.

Su and Liang ('40) studied the normal development of Chinese infants in Hunan, by measuring infants from two well baby clinics, and compared the data with that collected by the Iowa Child Welfare Research Station. They found that the Chinese infants in Hunan, Peiping and Tsinan were not smaller in early infancy than American babies, but their growth slowed down gradually a few months later. They considered that the slow growth in the latter part of the first year could probably be explained on a nutritional basis. The babies depended too much on breast feeding and were not given supplementary feedings in most cases.

Millis ('53) investigated the gain in weight and length in the first year of life of Chinese infants born in Singapore, in order to establish their growth curves for the first year of life. She found that the curves for Chinese infants in Singapore were similar to those for Chinese infants in China. The weight increased at a similar rate to that of white infants for about 20 weeks, but the Chinese infant made slower progress in the second 6 months of the year. At one year the average Chinese male infant was 47 to 54 ounces lighter than the white infant, and the female was 54 to 60 ounces lighter. The standards for white children were taken from Vickers and Stuart ('43).

In a further study Millis ('54) investigated the growth curves in the first year of life of Southern Indian infants born in Singapore. The Indian infant was lighter at birth than the Chinese infant and tended to gain weight more slowly and like the Chinese infant showed the retardation in growth in the second 6 months of the year. The Indian infants were on an average over 4 lbs lighter than white infants at the age of one year.

Rao and Bhattacharjee ('52) analysed the growth curves of Indian infants in the first month of life. Their families belonged to the middle class economic group, and they were normal full-term infants born to healthy mothers. They stated that the range of birth weights reported by various authors seemed to be a very wide one—the lowest they quote as 5 lbs 5 oz and the highest their own figure of 6 lbs 8.5 oz which is very similar to the author's figures for South African Indian birth

weights, 6.46 lbs. (Salber & Bradshaw '51). The new-born baby lost 8.6 to 10 oz in weight, (9% of birth weight) up to the third or fourth day, and thereafter steadily increased in weight, putting on 1.1 to 1.3 ounces per day until at the end of four weeks the weight reached was a little over 8 lbs. At four weeks the weight level of the South African Indian boys is 7.94 lbs and of the South African Indian girls 7.35 lbs. This study confirms the occurrence of the early rapid gain in weight previously mentioned.

NEGRO INFANT GROWTH STUDIES

Dodge ('27) analysed data of American Negro infants attending the University District Prophylactic Dispensary in Cleveland from 1914-1920. Converting his figures from grams to pounds gives the following results for weights at 3, 6, 9 and 12 months:

Boys	11.82 lbs	14.46 lbs	17.13 lbs	18.90 lbs
Girls	10.78 lbs	13.93 lbs	16.26 lbs	18.87 lbs

He states that the growth in weight of Cleveland Negro infants is definitely slower than the growth of white infants. It seems though, that the pattern of growth is not quite the same as that found in African children. Although the weights at three months are closer to the white weights than are the weights later in the year, even at three months they are well below European weights.

Bakwin and Patrick ('44) pointed out that though according to reports in the literature, the Negro infant was smaller at birth than the white infant and his growth during the first year was slower, it was not clear from the data whether these differences were due to innate or to environmental influences, since observations on Negro children had been limited to dispensary material.

Accordingly, they made a study on a group of Negro infants seen in private practice who were supervised from early life and given a good diet. They compared these babies with a group of white infants supervised from early life at the Fifth Avenue Hospital. There was no significant difference in the weight gain of white and Negro infants during the first year of life, and they concluded that "slower growth observed in earlier studies was due to differences in socioeconomic status rather than to differences in the nature of the germ plasm. Given the opportunity of proper medical supervision, Negro infants from moderate income families grow as well as white infants."

Scott *et al.* ('50) analysed the growth records of 654 Negro infants observed in private pediatric practice. These infants were from lower middle class families. Some of their conclusions are as follows:

"The mean birth weight for the male and female infants was 7.66 pounds and 7.20 pounds respectively. . . .

"At 12 months of age the weights attained were 22.59 pounds for male infants and 21.33 pounds for female infants. . . .

"We compared our results with data on Negro infants from various economic levels (general population, indigent, low middle class) reported in the literature. The infants in our study and those reported by Bakwin and Patrick surpassed those of other series in growth throughout the first year of life. A significant difference in growth was observed when indigent infants were compared with infants from middle class levels.

"We also compared our data with similar reports on the growth of white infants. There was no significant difference between the growth curves of Negro and white infants from comparable economic levels."

Meredith ('52) reviewed the literature on the size at birth and growth during the first postnatal year of North American Negro infants, and compared them with North American white babies. (See table 8). Meredith gives his figures in kilograms but the author has converted them to pounds in order to make comparison with her own figures easier.

For each Negro-white comparison within the period 1930-1950 there was approximate comparability in economic status and health care. The Negro group overall was of slightly lower economic level than the whites but all groups had reasonably adequate diets and sustained medical supervision.

In summary Meredith's findings as far as weight is concerned are:

1. Mean weight of viable Negro infants at birth is 3.23 kg (7.11 lbs), and mean weight of Negro infants weighing more than 2.2 kg at birth is 3.28 kg (7.2 lbs). The mean weights of white infants were higher by 0.12 kg (.26 lbs) and 0.13 kg (.29 lbs) respectively. The average North American Negro baby is over ¼ lb, nearly 4% lighter at birth than the average North American white baby.

2. The mean weight of Negro infants receiving adequate dietary and medical care from birth is 7.44 kg (16.37 lbs) at 6 months and 9.87 kg (21.71 lbs) at one year. Comparable means for white babies are higher by 0.20 kg (.44 lbs) and 0.13 kg (.29 lbs). At end of the first postnatal year the average well cared for North American Negro infant is not lighter than the average well cared for North American white infant by more than 2%.

From these studies of American Negroes it would appear that their growth pattern in infancy is different from that of South African Bantu and of Africans in Africa. When they are economically depressed their growth curve is generally lower than that of white infants and when

TABLE 8

Weight mean (lbs) at selected postnatal ages for North American Negro and White infants *

(*Adapted from Meredith, '53*)

INVESTIGATION	3 MONTHS No.	3 MONTHS Mean	6 MONTHS No.	6 MONTHS Mean	9 MONTHS No.	9 MONTHS Mean	1 YEAR No.	1 YEAR Mean
1. Baldwin	90	11.15	82	14.45	73	16.50	63	18.48
	118	11.35	109	14.63	87	17.47	53	19.89
2. Woodbury	301	12.21	279	15.47	245	17.18	182	18.92
	7046	12.89	7238	16.41	7152	18.59	6476	20.24
3. Dodge; Rude	208	11.48	155	14.56	145	16.70	119	18.79
	85	12.45	96	15.27	78	17.71	101	19.12
4. Michelson	1714	11.79	981	15.91	589	18.77	338	20.92
	180	12.91	219	17.07	167	20.33	100	22.77
5. Bakwin and Patrick	102	12.50	97	16.79	99	20.11	95	22.57
Bakwin and Bakwin	218	12.58	164	16.79	115	20.02	90	22.77
6. Pasamanick;	53	14.08	53	17.93	53	20.86	53	23.21
Norval, *et al.*	2518	12.50	1943	16.76	1508	19.73	1076	21.87
7. Kelly and Reynolds	108	12.10	100	16.46	84	19.49	46	21.45
	289	12.14	269	16.59	220	19.51	124	21.63
8. Scott, *et al.*	613	12.45	600	16.90	580	20.11	553	21.91
Vickers and Stuart	254	12.56	252	17.20	241	19.93	244	22.18
9. 1930-1950 Composite	2590	12.03	1831	16.37	1405	19.54	1085	21.71
	4538	12.50	3937	16.81	3245	19.82	2640	22.00
							MALES ONLY	
10. Rhoads *et al.*							99	21.96
							134	22.13

* In each comparison the upper figures are for American Negro infants and the lower figures for American white infants.

they are better off economically and have good medical supervision and adequate diet their growth is the same as that of whites of comparable circumstances.

Although the writer does not have figures of incidence of breast feeding among Negro mothers in the United States, her impression is that the incidence is far lower than amongst the non-European population in South Africa and in Africa as a whole. This impression is

borne out by the study done by Bakwin and Patrick, previously cited. Of the 114 infants seen in private pediatric practice that they studied, only 40% were breast fed for the first three to four months of life, the remainder being bottle fed. Bantu babies are breast fed whenever they cry and get adequate milk in early infancy, but they suffer when mothers' milk alone is insufficient for their needs, particularly after the second 6 months of life.

To increase the mean weights of European babies one should concentrate on more liberal breast feeding (or even bottle feeding) in early life, but to increase mean weights of non-European babies, on the whole, the emphasis must be placed on earlier introduction of suitable solids in adequate amount, and the maintenance of satisfactory mixed feeding.

We have demonstrated at health centres in Durban, that this can be done. At the Springfield Health Centre in 1948 Indian weights at one year had risen to 17 lbs 9 oz (17 lbs 6 oz in 1947) and Colored weights to 19 lbs 2 oz (18 lbs 11 oz in 1947). Data are not available for Bantu weights at Springfield for 1948. (These figures appear in the Training Scheme for Health Personnel Annual Report, 1948). When the Lamont Health Centre commenced its work in the Lamontville Native Location in 1948, there was a Municipal Child Welfare Clinic functioning in the area, which later closed down when the Heath Centre ran its own mother and baby sessions for the same clientele. I analysed the weight growth of the infants attending the Lamont Municipal Child Welfare Clinics in 1947 and 1948 in order to have a base line for comparison later on. The mean weights of the infants attending the Health Centre mother and baby sessions in 1950-1951 was compared with those of the municipal clinic, and we found that up to about the 30th week growth was about the same in the two peroids. After 30 weeks, however, the 1947-48 curve flattened out considerably and the average infant gained only 1½ pounds before the end of the 52nd week. The growth curve of the 1950-1951 group of infants flattened out less than the previous curve and they gained 2½ pounds in the same period, with a mean weight of 21.5 lbs at 52 weeks. (See Annual Report Lamont Health Centre 1950-51).

SUMMARY

1. Comparison of growth curves show that at the beginning of the year European babies are heaviest, Indian babies lightest, and that Colored and Bantu occupy an intermediate position with Colored babies slightly heavier than Bantu babies.

2. Colored babies weights are about the same as Europeans for about three months, and then fall progressively below them.

4. Indian babies grow as well as Europeans for about two months though their actual weights are always well below those of Europeans because of their difference in birth weight. After that they deviate increasingly from European till the end of the year.

5. Bantu babies overtake Europeans by about one month and their weights are above those of Europeans until 30 weeks of age, from which time they are below. All these remarks apply to both boys and girls.

6. Comparison of rate of gain shows that from two to 12 weeks Bantu boys gain more weight than all the other groups and from two to 8 weeks European boys gain the least of the four groups. European boys, however, gain more than the rest from 12 weeks onwards. From 16 weeks Colored boys gain more than Bantu and Indian.

7. Rate of gain of Bantu girls is greater than all the rest from 2–16 weeks, but European girls from two weeks onwards gain more weight than Colored and Indian girls. From 16 weeks Colored girls gain more than Bantu and Indian girls.

8. European babies gain far more weight than the other three groups in the second half of the first postnatal year.

9. The curve for South African European babies is similar to that of comparable babies in Europe and America. It is suggested that European infants are, on the whole, underfed in early life, due to the method of feeding on regular schedules and a fear of over feeding.

10. Non-European babies in South Africa, on the other hand, particularly the Bantu, grow well in early life, due to the high incidence of breast feeding which is given "on demand." When these babies need foods other than breast milk, growth becomes retarded because for reasons of poverty and ignorance the mothers do not supply a good and sufficient mixed diet.

11. Rapid early growth with marked slowing down in the second 6 months of life has been noted by investigators in Africa and elsewhere.

12. In America, on the other hand, where the Negro is very much a "poor white," growth of Negro babies is similar to that of white American babies, though on a lower level. When the economic groups are comparable and the infants have good medical supervision there is no difference in the pattern of growth between Negro and white American infants in the first year of life.

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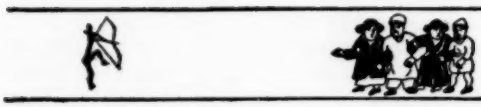

THE CONSTANCY OF PHYSICAL TYPES AS DETERMINED BY FACTORIAL ANALYSIS

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IN a previous paper (Hammond, '53) the author has assessed the constancy of factorial body types among children of school ages. The present paper extends the data to cover the period from birth to 5 years. This is the period over which the maximum growth occurs and, therefore, it is the one in which there is most likelihood of the pattern of measurements changing.

The first requirement of type constancy is that the type basis should agree from one study to another. The second requirement is that within the type basis the children should remain of the same type over a period.

EFFECT OF CHOICE OF MEASUREMENTS ON THE NATURE OF THE RESULTING TYPES

Although factor analysis is completely objective in the sense that the assumptions of the factorial methods can be set out and the techniques followed by anybody with the same results, yet the resulting types depend to a great extent on the nature of the measurements initially included. This, as emphasised by Howells ('51) is perhaps a fundamental disadvantage of the factorial method of determining types, but it is inevitable in *any* form of type determination. Apart from the obvious effect of an omission of any particular group of measurements, if one physical dimension is only weakly represented by the measurements, the resulting type analysis will tend to include measurements of other groups with this weak one in order to balance a particularly strong contrasting group. For this reason it is often found that a factor may consist of a number of oddly assorted items which are merely those which fail to fall into any of the other groups.

Batteries of measurements included in different authors' investigations seldom correspond completely and, therefore, any comparison

between the results must take account of this. The only rigorous way in which factors may be compared is to limit the analysis to those measurements common to the two studies; this is laborious as it involves a re-analysis from the correlation stage and it limits the amount of the data that can be included. In particular, if one is interested in the relative contributions of the general factor for physical measurements (representing isometric growth) and the type factors (representing allometric growth) in children of different ages it is necessary to include identical batteries of measurements, preferably taken upon a group with comparable age scatter. In the present studies where rigorous comparison is required, the data from different investigations have been re-analysed to produce exactly comparable sub-batteries of measurements. In other cases, however, the complete results have been used. In these latter the correspondence between results depends upon the fact that when some members of a battery of measurements are changed the factor saturations of the remaining variables alter very little. Examples are given of the change of saturation coefficients when the battery of measurements is augmented or reduced, but in some instances where the comparison is only intended to be general this relative constancy of the saturations has been assumed.

A simple measure of the over-all agreement between different results is the correlation between the factor saturations, and this measure has therefore been included.

A second major problem is what kind of factorial analysis to use. In the present case the simplest and most direct form of analysis, that of extracting a positive general factor and subsequent bipolar or contrasting general factors without any rotation, is used as the first basis for grouping the traits. Group factors are only invoked if this method proves inadequate to express the relations satisfactorily, for example when there is evidence of an odd number of groups or when the relations appear to apply to a small segment of the table of correlations only.

THE DATA

The present data consist of the author's measurements of a group of infants from the northern industrial town of Leeds (Hammond, '55b), measurements of school children (Hammond, '53b), Low's ('52) data for Aberdeen infants and Carter and Kraus' ('36) analysis of infants' measurements.

NATURE AND CONSISTENCY OF THE TYPE FACTORS

The first comparison is between the saturations derived from measurements reported on a small group of children living in Leeds who were measured annually from age one to 5 years. (Hammond, '55b). These results are also compared with those obtained from analysing the same battery of measurements taken on 200 boys and 200 girls aged 7, 9, 10 and 11 years, of similar social background from the same town and Sheffield (Hammond, '53b). The saturation coefficients for the general and bipolar factors derived from the different yearly measurement sets are shown in tables 1A and B. Table 2 gives the contribution of the general and type factors (percentage of total variance) for each year and the rank order correlations between the saturations for years 1–5 separately and 7–11 combined.

In practically all cases the type factor differentiates between the growth of long bones on the one hand, and breadth of trunk and limbs, on the other, and the corresponding types may be termed leptosomes (long narrow type) and eurysomes (broad short type). From the contributary variance figures it is evident that the type distinction is a rather minor one but apart from the saturations for the type factor for year 2 (boys) and year 5 (girls) the agreement between one year and another and between the infants and 7–11 year old children is quite close (see table 2). There was no consistent tendency for the general or type factors to increase their contribution to the total variance as the children increased in age.[1]

COMPARISON BETWEEN CONSISTENCY OF TYPE BASIS IN SCHOOL CHILDREN AND INFANTS

The constancy of the type saturations reported in the analysis of a somewhat different battery of measurements taken at ages 5–18 years (Hammond, '53a) was as follows:

Average rank order correlation = 0.83 (boys), 0.87 (girls), for the

[1] The correlations, and, therefore, the contributory variance of the general factor will increase as the age or size range of the subjects increases but unless there is a pronounced variation in shape with age this would be unlikely to affect the type variance appreciably. In any case the age scatter of the infants (2-4 months) and children (one year) were in such proportions as to result in very similar coefficients of variation of the measurements hence a direct comparison of contributory variances can be made.

TABLE 1A

Comparison of factor results at different ages; boys (Author's data)
Saturation Coefficients

Age	1		2		3		4		5		7-11 *	
Factor	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type
Height	.697	.548	.764	.673	.902	.284	.892	.309	.816	.203	.847	.482
Sitting height	.743	.261	.731	.134	.730	.218	.906	.197	.639	.329	.819	.241
Leg length	.647	.307	.657	.180	.793	.276	.823	.259	.973	.177	.811	.356
Chest depth	.351	.093	.330	.013	.180	—.251	.286	—.400	.331	—.577	.632	—.126
Chest breadth	.450	—.140	.486	—.029	.309	.343	.450	.141	.597	.230	.693	—.194
Knee breadth	.558	—.191	.725	—.152	.845	—.400	.738	—.480	.653	—.231	.860	—.156
Ankle breadth	.583	—.045	.691	.280	.775	—.240	.783	—.131	.752	—.586	.801	.013
Interspinous breadth	.545	—.195	.641	—.214	.178	—.053	.562	.330	.477	—.030	.647	.052
Interacromial breadth	.495	—.195	.642	—.266	.638	.228	.665	—.024	.613	.518	.747	.020
Arm girth	.738	—.276	.369	—.341	.471	—.216	.477	—.251	.088	—.119	.690	—.460

* Note: means, variances and co-variances were calculated within years.

TABLE 1B

Comparison of factor results at different ages: girls (Author's data)
Saturation Coefficients

Age	1		2		3		4		5		7-11 *	
Factor	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type	Gen.	Type
Height	.733	.230	.856	.364	.914	.183	.745	.506	.858	.492	.835	.519
Sitting height	.697	.165	.817	.238	.838	.314	.870	.203	.682	.450	.802	.278
Leg length	.615	.247	.582	.553	.825	.193	.710	.356	.742	.190	.828	.269
Chest depth	.411	.032	.506	—.151	.367	—.630	.159	—.339	.529	.019	.654	—.150
Chest breadth	.519	—.245	.617	.037	.581	—.316	.463	—.070	.535	—.118	.691	—.099
Knee breadth	.619	.070	.808	—.299	.783	.027	.803	—.102	.823	—.283	.838	—.229
Ankle breadth	.427	.234	.748	—.096	.750	.293	.660	.059	.778	—.433	.666	—.168
Interspinous breadth	.552	—.250	.602	—.114	.565	.125	.709	—.136	.477	—.144	.620	—.072
Interacromial breadth	.596	—.364	.847	—.002	.606	—.023	.637	.044	.699	—.080	.677	.239
Arm girth	.692	—.250	.650	—.469	.665	—.254	.615	—.517	.613	—.005	.665	—.595

* Note: means, variances and co-variances were calculated within years.

general factor; 0.94 and 0.97 for the first type factor; and 0.74 and 0.77 for the second type factor. Again, there was no clear tendency for the type differentiation either to increase or decrease with age.

We now have a situation where two different batteries of measurements, those of the pre-school children and school children, respectively, give fairly consistent groupings of the measurements but because of the choice of measurements, the resulting types necessarily differ. Children in the pre-school group were divisible into length-breadth (leptosome-

TABLE 2

Contributary variances and rank order correlations between saturation coefficients obtained for years 1-5 and 7-11 compared with the average rank

	GENERAL FACTOR				TYPE FACTOR			
	Contributary variance		ρ		Contributary variance		ρ	
	boys	girls	boys	girls	boys	girls	boys	girls
Year 1	35.2%	35.4%	.75	.78	6.9%	5.2%	.81	.65
Year 2	39.9%	49.7%	.95	.75	8.1%	7.7%	.61	.94
Year 3	40.8%	49.7%	.90	.95	7.0%	8.1%	.81	.72
Year 4	47.2%	43.5%	.96	.82	7.9%	8.4%	.78	.98
Year 5	41.6%	47.0%	.82	.88	12.4%	7.9%	.70	.47
Years 7-11	57.6%	53.6%	.91	.89	7.1%	9.5%	.81	.91

eurysome types) and in the school children's groups the major differentiation was between length and girth (leptosome-pyknic types) with the breadth (being weakly represented) thrown into the length group. However, for the school children's groups, lengths, breadths and girths were all shown to be distinct when the breadth and length or breath and girth measurements were analysed separately.

For example, when 21 breadths and girths were analysed by a bi-polar analysis they formed two distinct groups, the only exception being knee breadth which formed part of the girth group (but as its saturation for the type factor was less than 0.1 it was not significant). Similarly, when lengths and breaths alone were analysed the type factor differentiated between these groups without exception. A bi-polar analysis applied to a battery containing length, breadth and girth measurements must necessarily result in a mixed grouping for the type factor. We would, therefore, expect three type components, length, breadths and

girths to show up if a group factor analysis were applied to the appropriate measurements.

At ages 3, 4 and 5 years measurements of chest girth, weight and sub-cutaneous fat were added to the battery and a group factor analysis was applied.[2]

TABLE 3

General and group factor analysis of 13 measurements (boys)
Factor saturations

	AGE 3				AGE 4				AGE 5			
	General factor	Group factors			General factor	Group factors			General factor	Group factors		
		1	2	3		1	2	3		1	2	3
Height	.60	.60			.82	.48			.79	.38		
Sitting height	.64	.38			.82	.42			.54	.46		
Leg length	.53	.55			.75	.43			.85	.41		
Chest breadth	.19	.37			.42	.22			.55	.28		
Acromial breadth	.33	.58			.63		.26		.43	.48		
Chest depth	.16		.37		.37		.40		.29		.43	
Spinous breadth	.29		.06		.52	.41			.41		.12	
Knee breadth	.84		.01		.77		.16		.84		.04	
Ankle breadth	.69		.14		.85		.48		.65		.39	
Arm girth	.53			.19	.41			.58	.10			.50
Chest girth	.75			.16	.74			.00	.06			.37
Subcutaneous fat	—.06			.55	.34			.48	—.09			.50
Weight	.90			.10	.90			.17	.91			.60

As shown in table 3 the three type factors represent respectively (1) long bone measurements (with shoulder breadth), (2) trunk and limb breadths (with chest depth) and (3) measurements affected by the soft

[2] The method of analysis used was to sort the variables initially according to the first three factors of the bi-polar analysis, then calculate new basic factor saturations by the ordinary summation method of Burt's ('40, p. 459) general factor procedure, but using approximations for the whole trace consisting of those correlations which are augmented by the group factors instead of for the diagonal element alone. The sums of the elements of the trace were calculated as the products of the provisional basic saturation coefficient for each variable times the sum of the saturations of the other variables contributing to the group. The result is to produce a battery in which the general factor is not influenced by the group factors and from which they rise as positive clusters above the basic general factor level.

tissues, namely, arm and chest girths, weight and sub-cutaneous fat.[3] Clearly a larger battery of measurements is required to define these factors more adequately. At age 5, 22 measurements and at 7–11 years,

TABLE 4

Comparison of group factor saturations

	BOYS								GIRLS							
	5 year group Group factor			7-11 year group * Group factor					5 year group Group factor			7-11 year group * Group factor				
FACTOR	1	2	3	1	2A	2B	3		1	2	3	1	2A	2B	3	
Height	.730			.653					.730			.760				
Sitting height	.414			.545					.512			.595				
Leg length	.540			.585					.533			.728				
Arm length	.456			.635					.427			.654				
Foot length	.412			.588					.574			.599				
Hand length	( )			.585					( )			.517				
Interacrom. br.	.349			.325		.236			.429			.517		.091		
Foot breadth		.125		.343	.306					.051		.348	.501			
Hand breadth		.450		.346	.406							.496	.488			
Ankle breadth		.548			.308					.219			.500			
Knee breadth		.026			.285					.319			.487			
Wrist breadth		.469			.487					.173			.513			
Elbow breadth		( )			.361								.458			
Chest depth		.029				.030					.426					
Chest breadth			.263			.139					.506			.190		
Interiliac br.		( )				.330								.369		
Inter-spin. br.	.114					.368								.433		
Inter-troch. br.			.234			.236			.263					.216		
Wrist girth					.419								.511			
Ankle girth					.276								.579			
Arm girth			.557				.620			.671	.265		.495		.682	
Knee girth			.415		.193		.508			.250	.475				.547	
Calf girth			( )				.487				( )		.519		.506	
Chest girth			.366				.418				.284				.444	
Waist girth			.662				.502				.485				.543	
Hip girth			.564				.522				.490				.543	
Fat			.710				.713				.520				.764	
Weight			.384				.426				.424				.453	

* Note: means, variances and co-variances were calculated within years.

29 measurements were taken consisting of measurements of long bones, girths and breadths of limbs and trunk together with weight and sub-cutaneous fat. The results of applying a similar group factor analysis to the correlations are shown in table 4.

[3] The effect on the general factor saturations of adding variables is only slight, the rank order correlations (ρ) between the original saturations and new general factor saturations were .89, .99, .98 (boys) at ages 3, 4 and 5 years, respectively,

The group factors which result from the two batteries of measurements for boys and girls agree fairly well; there is no major discrepancy in the grouping of the variables which are common to both studies. Again three group factors result, corresponding to a factor for length measurements, another for bone breadths, and a third for girths with weight and fat. In the school children's group the breadth measurements could be subdivided into limb breadths together with ankle and wrist girths—which were minimum measurements largely concerned with bone formation (designated factor 2a) as distinct from trunk breadths (designated factor 2b). In boys, calf girth appeared in the girth group and also in the limb breadth group but only in the girth group for girls. Foot and hand breadth also showed some overlap appearing in the long bone group and in the limb breadth group (factor 2a).[4]

These results show fairly clearly that when a sufficiently wide selection of body measurements is taken they can be differentiated into long bone measurements (including shoulder breadth) as the major group, girth measurements involving muscle and fat, as the next important group and breadth of limb bones and trunk as a less homogeneous third grouping. These are apart from any head or face measurements which also show their own groupings.

COMPARISON WITH OTHER STUDIES

The foregoing comparisons have been made between the author's own studies where many or all the measurements have been the same. Since the saturations of the common variables have remained much the same when measurements have been added, it is legitimate to compare the order of saturations of the variables common to these and the results of other investigators without requiring that all the measurements should be the same and without having to reanalyse the common parts of the tables. This has been done in comparing the present results with those of Carter and Kraus' analysis of the Bakwins' data and the author's analysis of correlations between body measurements derived from Low's

compared with correlations of .77, .86, .81 for ages 3 with 4 and 5 years, and 4 with 5 years, respectively, for the same children and the same battery of measurements. This is evidence in favor of the general factor being very little different in the two cases and therefore representing true all round growth, rather than merely the common elements of a limited number of measurements.

[4]Hammond ('42) also gave hand breadth in the long bone factor.

Aberdeen study even though Carter and Kraus' study included many head measurements. The results are set out in table 5.

The major body measurement can be differentiated into length and breadth or girth measurements with very minor exceptions.

TABLE 5

Factor saturations; comparison with other results

	BOYS			GIRLS		
	Carter & Kraus	Low	Hammond	Carter & Kraus	Low	Hammond
Total length	.54	.32	.46	.52	.36	.30
Sitting height	.58	.23	.30	.51	.11	.20
Leg length	.34	.27	.32	.34	.51	.28
Foot length	—	.30	—	—	.19	—
Cubit length	—	.36	—	—	.28	—
Palm length	.14	—	—	.15	—	—
Middle finger length	—.26	—	—	—.28	—	—
Head length	—	—.15	—	—	—.11	—
Shoulder breadth	—.06	—.31	—.24	00	—.35	—.29
Hip breadth	—.30	—.23	—.18	—.42	—.14	—.24
Chest breadth	—	—	—.18	—	—	—.27
Chest depth	—	—	.07	—	—	.01
Chest girth	—.09	—.23	—	—.06	—.18	—
Upper arm girth	—	—	—.40	—	—	—.27
Palm breadth	—.11	—	—	—.02	—	—
Head breadth	—	—.50	—	—	—.28	—
Knee breadth	—	—	—.19	—	—	.06
Ankle breadth	—	—	—.06	—	—	.18
Weight	.40	—.20	—	.36	—.28	—

To summarise the findings: the factors distinguish between length measurements, which are probably affected by the state of closure of the epiphyses, and the girth measurements which are affected by the amount of overlying fat and muscle tissue.[5] Besides this major distinction there

[5] Analyses of measurements of subcutaneous fat taken at different sites of the body always show such high correlations with each other and low correlations with other body measurements as to indicate a very strong group factor (Brožek and Keyes, '51; Hammond, '55a). The presence of a similar factor for muscle development alone has not been shown in the tables reported here since the techniques used were not capable of differentiating adequately between muscle and fat. (Measurements of breadths across the chief muscles with blunt-pointed

are two sub-groups corresponding to limb breadth development or trunk breadth development and these are related to some extent. Which of these groupings appears first, that is, whether all trunk or all limb measurements go together or whether the breadths go together irrespective of whether they are on trunk or limbs depends largely upon the combination of measurements included in the whole battery. However, in all the batteries of measurements studied the groupings have been limited to the above combinations. These results are all obtained with unselected populations—if persons were to be selected according to their physical characteristics, almost any combinations of measurements could be produced.

THE INDIVIDUAL'S TYPE CONSISTENCY

So far we have only considered the consistency of the type basis. We can say that similar types appear consistently in all ages of children studied; there are leptosomes at birth, during the pre-school years and throughout the school years, but it does not follow from this that the individuals who are leptosome at birth or in infancy will necessarily be so at the later ages. To check this we must assess the constancy of the individual type measurements. This can be done in terms of weighted type factor measurements based on regression equations, simple sums of diagnostic measurements or ratios of measurements indicative of body type. In the study of school children, regression equations were used to calculate the individual's type measurement and the resulting factor measurements gave continuous distributions. On being repeated after an interval of three years the factor measurements gave correlations ranging from 0.65 to 0.92 for the different sex, age and social groups. The percentages changing type (on a twofold classification) averaged 11% up to 13 years and 18% from 14 onwards in boys, compared with 8% up to 9 years, 12% over 14 and 22% during the ages 10–13 for girls. In these cases the growth between the intervals of measurement was slight compared with the degree of existing type differentiation. In the case of infants, growth from birth to 5 years is relatively much greater so that we should expect more type changes to occur.

At one year of age the babies were typed using an unweighted sum

calipers using sufficient pressure to eliminate the fat contribution, or measurements of X-rays at different parts of the body would be needed to show a group factor for muscle development as a sub-group of the girth component.) A rating for muscularity can also be made by adjusting for the fat covering contributing to girth measurements.

of length and diagnostic breadth measurements which had equal standard deviations (in order to remove any bias if one type grew more than the other) and from the continuous distribution of factor measurements the middle 50% were selected (equivalent to taking the mean $\pm$ 1 p. e.)

TABLE 6

Mean measurements for three physical types selected at age one year with sample re-measured at age 5 years

	Leptosomes		Mesosomes		Eurysomes	
BOYS	1 yr	5 yr	1 yr	5 yr	1 yr	5 yr
Number	70	7	84	14	60	15
Weight (lbs)	21.5	41.2	23.3	39.7	22.9	39.9
Height (cm)	75.2	110.1	72.9	108.5	71.5	107.4
Sitting height	46.7	62.7	45.3	61.6	43.9	60.6
Leg length	30.6	50.5	29.3	49.4	28.3	51.9
Bi-iliac breadth	11.4	15.6	11.6	15.5	11.6	15.5
Bi-acromial breadth	17.0	23.5	17.2	24.0	17.6	23.6
Chest breadth	13.7	17.0	13.7	17.4	13.9	17.4
Chest depth	12.6	13.6	12.2	13.5	12.3	13.8
Arm girth	15.8	16.5	15.7	16.7	16.0	16.6
Knee breadth	5.58	7.68	5.45	7.60	5.50	7.54
Ankle breadth	3.58	5.24	3.58	5.15	3.46	5.12
GIRLS						
Type 'score'	57.1	52.1	53.0	46.8	48.9	48.3
Number	58	5	116	15	63	19
Weight (lb)	21.6	42.5	21.8	40.7	21.8	40.4
Height (cm)	73.9	111.4	72.0	109.1	70.2	107.7
Sitting height	45.9	62.5	44.6	60.9	43.5	60.6
Leg length	30.5	50.9	29.3	50.4	28.2	49.9
Bi-iliac breadth	11.4	15.3	11.3	15.7	11.5	15.2
Bi-acromial breadth	16.5	24.1	17.0	24.0	17.2	23.5
Chest breadth	13.4	17.5	13.5	16.9	13.7	17.1
Chest depth	12.2	13.6	12.0	13.4	12.1	13.5
Arm girth	15.1	17.0	15.5	16.8	15.7	17.2
Knee breadth	5.39	7.60	5.34	7.34	5.36	7.44
Ankle breadth	3.43	5.27	3.33	5.15	3.34	5.15
Type 'score'	57.0	51.2	52.6	48.5	48.7	47.0

as the mesosomes and the outer 25% forming the length group as leptosomes and the broadest 25% as the eurysomes. The mean measurements of these three types at ages one year and 5 years are shown in table 6. The measurements show the average type characteristic and

at age 5 the original groups ase still distinct, although the eurysomes and mesosomes now show little difference in their mean type 'scores' as shown by the figures at the foot of the columns in table 6. If, now, individuals are re-allocated to types on the basis of the fifth year measurements and their correlations, three type groups can again be recognised. These show much the same differentiation as the first year types but are composed of slightly different groupings of individuals. As we might expect, the type pattern for these groups is more distinct than for the children typed 4 years before, showing that the intervening growth has tended to mask the type distinction. The new type measurements are shown in table 7.

TABLE 7

Mean measurements for three body types re-selected at age 5 years

	Leptosomes		Mesosomes		Eurysomes	
	Boys	Girls	Boys	Girls	Boys	Girls
	7	10	14	17	9	10
Weight	40.5	41.1	40.4	39.6	38.6	43.2
Height	110.6	114.9	109.5	108.1	105.3	107.7
Sitting height	63.5	62.4	61.4	60.3	59.8	60.5
Leg length	49.9	52.1	49.7	50.1	47.9	49.7
Biacromial breadth	23.36	23.78	23.93	23.67	23.83	23.85
Bitrochanteric breadth	19.21	19.13	19.36	19.28	19.22	19.45
Chest breadth	16.93	16.72	17.75	17.17	17.33	17.20
Knee breadth	7.61	7.30	7.58	7.31	7.58	7.72
Ankle breadth	5.26	5.04	5.15	5.14	5.08	5.30
Chest depth	13.42	13.22	13.82	13.58	13.50	13.40
Arm girth	16.30	16.66	16.66	16.54	16.86	18.34
Chest girth	55.0	53.8	55.6	53.9	54.4	56.1
Body fat	33.0	34.0	32.6	35.9	34.0	47.6
Type 'score'	46.7	52.1	39.7	40.3	33.2	34.2

The actual numbers of type changes from age one year to age 5 compared with the numbers expected (in brackets) were as follows: 42% (50%) one type change; from mesosome to eurysome or leptosome, or the converse, 6% (14%) two changes; from eurysome to leptosome, or the converse. All the extreme changes were from eurysome to leptosome at the second typing. The χ^2 value, 13.1, shows that as few changes as this would be expected to appear only about one in a 100 times had there been no association between the types. That is, there was a significant type consistency over the period although it was not high. The correlations between type scores at one year and 5 years were .51 and .30 for

boys and girls, respectively. Similar results for children who were typed at age two in comparison with their type at age one showed that 41% of the boys and 58% of the girls changed their type from mesosome to eurysome or the converse (compared with an expectation of 49%) but only 2% changed from eurysome to leptosome or the converse (compared with an expectation of 17%). Thus 57% of the boys and 40% of the girls remained classified the same on both occasions compared with an expectation of 34%. The correlations between the type values at first and second year measuring were 0.71 for boys, and 0.52 for girls.

In sample groups of 64 school boys aged 8 years and 78 girls aged 7 years, the correlations between the first and second unweighted type measurements after an interval of three years were 0.86 and 0.69 respectively. If the growth in length and girth were unrelated to the type, the expected correlations would be 0.60 and 0.72. The boys, but not the girls, have therefore shown greater type consistency than would be expected from the contribution which the first measurements make towards the later measurements. In th girls' group a few individuals made extreme changes, some through being unusually fat at the first measuring and later showing more average proportions, and others through increasing in fat and therefore in girths. There were 4 changes of type (on a two-fold classification) among the boys (all being borderline cases at both measurings), but 8 girls changed their type, two of them markedly.

In the same way type ratios may be studied from one year to the next and table 8 shows the correlations between

$$\frac{\text{weight}}{\text{height}} \quad \frac{\text{height}}{4 \times \text{biacromial breadth}} \quad \text{and} \quad \frac{\text{chest girth}}{\text{height}}$$

(all of which can be used as type indicators) for the Leeds children or Low's Aberdeen children from birth to 5 years.

TABLE 8

Correlations between type ratios for successive years from birth to five years and 10-13 years

		N	birth–1	1–2	2–3	3–4	4–5	N	10–13
Ht./biacrom	Boys	66	.04	.49	.37	.59	.78		
(Low)	Girls	60	.08	.42	.32	.76	.73		
Chest/Ht.	Boys	66	.43	.51	.56			200	.82
(Low)	Girls	60	.15	.59	.76			200	.70
Wt./Ht.	Boys	66	.40	.57	.70	.66	.81		
(Low)	Girls	60	.09	.32	.67	.80	.86		
Wt./Ht.	Boys	214	.10	.50				200	.88
(Hammond)	Girls	237	.16	.50				200	.97

Correlations between measurement types and type ratios were as follows:

	Boys	Girls	
Ht./4 x Biacrom.	.55	.80	
Chest/Ht.	.86	.89	
Wt./Ht.	.38	.48	(with length breadth type distinction)
Wt./Ht.	.64	.59	(with length girth type distinction)

The correlations between the weighted combination of height and biacromial breadth at birth compared with later ages to 5 years (not shown) were around zero and similarly for the other ratios, showing that the physical characteristics at birth bear only slight relation to the later body form. The above figures show that the correlations between successive years' measurements increase with age.

TYPE CONSISTENCY IN TERMS OF GROWTH PATTERN

The above type consistency is partly a necessary consequence of the fact that growth between successive intervals of measuring may be so slight (relative to the variation in attained measurements) as to be incapable of upsetting the type position once established, whatever the nature of the growth. A more fundamental type consistency would be that in which the individual having become differentiated into a type at birth, say, will then proceed to grow in a way which maintains or accentuates this configuration. We need, therefore, to see whether growth itself shows type characteristics and to study the growth which occurs in different physical types.

In the first place, if there is type or directional growth it should be apparent in the same way that measurement types could be recognized from the analysis of correlations; in this case, the correlations would not be between attained measurements but between growth increments. The growth increments calculated from Low's children from birth to 5 years and the Leeds children from one to three years have been correlated and the results of factorising the correlations are shown in table 9.[6]

[6] After age 5 the differences in birth measurements are so small relative to the attained measurements that the correlation between increments from birth will be virtually the same as the correlations between the attained measurements and, therefore, types of growth will be much the same as the measurement types.

The grouping of growth (*i. e.*, type growth) which becomes evident after the general growth influence has been partialled out follows a distinction into length and non-length growth similar to the classification of attained measurements. The general growth influence is again stronger than the differentiating growth influence; the general growth

TABLE 9

Factor saturations for children's growth

	GENERAL FACTOR SATURATIONS			TYPE SATURATIONS		
	Aberdeen (Low)[1]		Leeds (Hammond)[2]	Aberdeen (Low)[1]		Leeds (Hammond)[2]
	Boys	Girls	Boys & Girls	Boys	Girls	Boys & Girls
Stature	.840	.723	.710	.306	.455	.407
Sitting height	.825	.802	.479	.080	.286	.375
Leg length			.265			.150
Cubit	.510	.722		.250	.327	
Foot length	.577	.553		.118	.076	
Head length	.293	.601		.050	.134	
Head breadth	.320	.485		—.129	—.061	
Inter-acromial br.	.108	.369	.402	.250	—.395	—.235
Inter-trochanteric br.	.330	.585	.009	—.392	—.365	—.113
Chest depth			.092			—.236
Chest breadth			.550			—.504
Ankle breadth			.452			.021
Knee breadth			.488			.107
Chest girth	.400	.619		—.395	—.270	
Arm girth			.299			—.238
Weight	.730	.899		.194	—.149	

[1] Birth to 5 years.

[2] One to three years.

factor contributions to the total variance being 29.5% boys, 43.5% girls (Aberdeen) and 18.1% (Leeds children) compared with the type factor variance of 6.4%, 7.2% and 7.9%.

The variance of the type or directional growth ranges from 1/6 to 2/5 of the variance of all-round growth, depending upon the interval. Therefore, even if the type growth were perfectly correlated with the attained measurements at a fixed age we would still find that children would tend to grow in all directions irrespective of their type. Only when these general growth differences were allowed for, would the relatively greater length or breadth growth have its effect.

Having shown that type growth does occur but that it is much less evident than general all-round growth, we need next to see whether it is related to the existing body type; *i. e.,* do leptosomes continue to show relatively more length growth, pyknics growth in girth and eurysomes growth in breadth?

The three type groups in the original Leeds sample of 451 children classified at one year of age on the basis of length and breadth development into leptosomes, mesosomes and eurysomes, showed the same weight increase (this being a good indicator of all-round growth) from birth

TABLE 10

Mean growth from one year to 5 years according to physical type

		Leptosomes		Mesosomes		Eurysomes	
	n.	7	5	14	15	15	19
		Boys	Girls	Boys	Girls	Boys	Girls
Weight	lbs	19.7	20.9	16.4	18.9	17.0	18.6
Height	cm	35.1	38.0	35.6	37.1	36.3	37.1
Sitting height	"	15.2	16.4	16.3	15.9	16.5	16.9
Leg length	"	20.0	20.7	20.1	20.4	23.2	21.3
Interacromial breadth	"	5.94	7.63	6.31	6.71	5.41	5.91
Interspinous breadth	"	3.83	4.20	3.67	4.15	3.90	3.56
Chest breadth	"	3.30	4.32	3.68	3.62	3.54	3.53
Chest depth	"	0.90	1.68	1.50	1.50	1.54	1.30
Knee breadth	"	2.23	2.37	2.21	2.04	2.08	2.09
Ankle breadth	"	1.82	1.99	1.69	1.89	1.52	1.74
Arm girth	"	0.58	1.60	1.12	1.60	0.54	1.42

to one year (Hammond, '52). This is confirmed by Low's data where correlations of weight increase with type measurements are also all about zero. The mean weight increase and growth in all the other dimensions for a sample followed up from one year to 5 years for the leptosome, mesosome and eurysome types, are shown in table 10.[7]

The growth shown by the three types is similar in pattern but the leptosome girls gained more in all measurements. The other types actually gained *relatively* somewhat more in length than the leptosomes

[7] Although the figures at age 5 are based on less than a fifth of the group measured at age one, the results can be accepted with greater confidence than their small numbers would suggest because this sub-sample had practically identical measurements with those of the original group (table 6) and they also agree very closely with the means for a larger group of children from other northern towns studied on another occasion (Hammond, 1953b).

who tended to 'fill out' and broaden. This accounts for the fact that the original types show a diluted form of differentiation at age 5 compared with groups selected afresh, and that hardly any distinction remains between the measurements of the original mesosome and eurysome types.

The total increase in weight shown by the leptosome and pyknic types in the school children's sample referred to previously did not differ. The types also gave the following totals of length and girth growth (equivalent to type growth) over an interval of three years.

	SUM OF LENGTH GROWTH cm		SUM OF GIRTH GROWTH cm	
	Boys	Girls	Boys	Girls
Leptosome	36.4 ± 1.1	36.3 ± 1.0	25.1 ± 1.3	28.5 ± 1.8
Pyknics	37.4 ± 1.2	36.4 ± 1.0	23.2 ± 1.6	22.2 ± 1.4

Only the girls' increase in girths was significantly different for the two types: the pyknics increased their girth *less* on average than did the leptosomes. This accounts for the correlations between first and second typing being less than expected if growth were random with respect of initial type in the case of girls.

In young children there is little consistency in type but if one examines other aspects of development the same unpredictability is found; for example, correlations between attained weights or heights at birth and at periods up to 5 years are only what would be expected from random growth superimposed upon the attained measurements at any moment.

TABLE 11

Correlation between attained weight and height with birth weight and length

	Birth to 1 year			2 years			3 years			4 years			5 years		
	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*	n	Obs	Exp*
WEIGHT															
Boys	214	.49	.42	44	.33	.43	24	.44	.40	34	.39	.31	30	.38	.38
Girls	237	.22	.42	45	.67	.38	35	.07	.27	40	.16	.22	37	.17	.22
HEIGHT															
Boys		.55	.60		.22	.48		.27	.37		.29	.37		.35	.34
Girls		.26	.54		.39	.45		.24	.40		.30	.36		.30	.33

* Expected correlation is based on the assumption that

$$r = \sqrt{\frac{\text{birth weight variance}}{\text{birth weight variance} + \text{variance of growth}}}$$

Although the correlations are significant they are not higher than would be given by assuming the intervening growth to be independent of the birth measurements. Moreover in the case of lengths, the variances of the separate yearly growth may be added to give the variance of the growth from birth to any age (showing that there is negligible correlation between the successive annual gains). Another aspect of growth affecting type consistency is that the growth in different dimensions shows spurts or troughs in the same individual and the correlations found between weight gain from birth to two years and from 3-5 years were around zero.[8] For height gain, which in girls showed the greatest consistency, the correlation only equalled 0.26 and was zero for boys. Type growth (difference between length and breadth increases) only gave correlations of 0.15 for girls and 0.08 for boys over the two periods.

There is fairly considerable evidence (Weir '52, Hammond '53b) that the higher social classes are more leptosome than the lower ones. In addition they show greater relative length growth than weight growth so that the socially determined types increase their type differentiation as they increase in age. This is shown clearly by the means of different children at different ages and also by following up the actual growth.

The author's work on groups of children of different nutritional state has also shown that the groups with poor nutrition contain a bigger proportion of leptosomes but that, in addition, their growth tends to accentuate this pattern. On groups of more homogeneous social background reported here, on the contrary, there appears to be little relation between the type and the ensuing growth.

DISCUSSION

The most difficult part of the interpretation of physical types emerging from the present analyses is to account for the level of consistency (or its absence) in children of different ages. It is fairly clear that the same kinds of types can be distinguished at all ages from infancy to adulthood, and that when growth is analysed it also falls into similar patterns. However, whilst growth can accentuate or decrease the type distinction, a child's measurements at the later ages will necessarily bear some relation to what they were earlier, even as far back as birth, on account of the contribution of the first attained measurements to the later ones.

[8] The intervals were chosen to avoid consecutive periods, as any measuring errors would tend to give negative correlations.

The period from birth to 5 years covers the maximum growth and indeed includes about half of the total growth that occurs in length and 2/5 of the total weight gain from birth to adulthood, so that to test for type consistency between birth and 5 years is equivalent to testing that from 5 years to maturity (the coefficients of variation being comparable at the two ages). This is therefore a rather strict test. In later childhood, by contrast, just because growth is so slight relative to attained measurements, the type consistency must be relatively high. Even at adolescence the change in growth pattern is still relatively slight as well as being temporary (due to the different times of onset of measurement spurts) and so type consistency will still be fairly high over this period. The correlations found between the type values over an interval of three years for school children (even including the adolescent period) average over 0.8. In part, the high type consistency is due to this contribution of the earlier measurements to the later body form but also the analysis of the growth shows that it consists mainly of a general increase in all directions and this does not alter the type. Part of the growth is differentiated into directions corresponding to relatively greater or lesser increase of lengths, girths or breadths in much the same way that the attained measurements were grouped.

This correponds to true type growth, yet in the groups studied it has been very difficult to demonstrate any correlation between the kind of growth which occurs and the different attained body types. In those type groups which were also distinguished by social class, the leptosomes tended to become more clearly differentiated from the pyknics and this was also true to a lesser degree of a group in which the types were associated with nutritional state, but the types as such have on the whole failed to show specific growth characteristics. This may partly be due to the fact that growth itself is not consistent from one period to another as shown by the present study, the author's unpublished growth analyses of other groups, and also previously by (Muhsam '47). In general it looks as though the growth is randomly superimposed on the body types found at any moment. The result is that most individuals, whatever their type may be, tend to increase in general size by greater or less amounts during any interval. However, in addition some few will accentuate their type becoming relatively longer, more rotund or broader, others tend to compensate and so decrease their type shape but most continue to maintain their proportions. A balance between these opposing tendencies is necessary if an amorphous inter-type is not to result. The rather slender evidence afforded by the contributory variance of the type and general

factors at different ages suggests that there is no clear tendency for types to become more strongly differentiated at any one part of the growing period than another. The constancy of the types will naturally be highest at those times where the growth is least, *i. e.,* from about 5 years to 10 or 11 years. Temporary changes of type may occur at adolescence due to the time lag between the growth spurts of different parts of the body. In adults entirely different conditions apply because the all-round growth which characterises childhood no longer occurs. In adults weight and the girths may change considerably mainly through the accumulation or loss of fat, but lengths do not alter comparably and, therefore, whatever weight change occurs is more likely to alter the type form.

SUMMARY

Factor analyses of body measurements for infants from birth to 5 years have shown that length, girth and breadth types similar to those found in children of school ages can be distinguished uniformly throughout the age range.

Analyses of the Bakwins' and Low's data confirm these distinctions. The types are probably determined by the relative development of the long bones, muscle and fat.

The consistency of the individual type values has been assessed over an interval of 3–5 years at various age levels. The type consistency is low in infancy and increases throughout the school ages largely because the variance of the first measurements contributes an increasingly greater part to the variance of the second measurements in older children.

Factor analysis of growth increments showed a distinction into relatively greater length, girth or breadth development similar to the types of attained measurements, but the type growth was less important than general growth and showed little consistency from one period to another. Within the same social and nutritional levels the type growth did not appear to be related to the physical type.

The type consistency found could be explained in terms of growth randomly superimposed on the initial type figure except where the attained types were also related to social or nutritional influences. In these cases the types also showed a consistently different growth pattern.

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TYPICAL AND ATYPICAL CHANGES IN THE SOFT TISSUE DISTRIBUTION DURING CHILDHOOD

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INTRODUCTION

IN anthropometric studies on body build and physical development of white children in New Jersey (Kornfeld '47, '53, '54, '55) we tried to analyse the changes occurring in the distribution of the subcutaneous fat tissue during childhood.[1] The same selection of measurements and the same technique was used which we had developed for earlier studies in Vienna (Kornfeld and Schüller '30), with the exception that an anthropometric caliper was used instead of the small micrometer used before. Results obtained this way may not be as accurate as those obtained by the more recently developed methods of examination (measuring skinfolds with special calipers which allow a constant pressure,—Franzen '29, McCloy '36, '38, Brožek '53,—and roentgenometric determination of subcutaneous fat layers, Garn '55a, Stuart, Hill and Shaw

[1] The following measurements were taken on these children since 1940: body length, stem length, weight, head circumference, supramamillary chest circumference; circumferences of wrist, forearm, arm, and calf; hand length, hand breadth and middle finger length. Since 1950 the following were added: fronto-occipital and biparietal diameters of the head, chest circumference at the level of the xiphoid, foot length, foot breadth and bimalleolar diameter. Finally in 1952 we resumed the soft tisue measurements, which are discussed in this paper and which we had not used since our studies in Vienna.

Longitudinal studies were considerably handicapped by the fluctuating character of our pediatric practice. Even in the limited number of cases which were regularly examined over a long period of time, the first group of measurements enumerated above could be followed on the same individual for a period of 14 years; the second group for 6 years, at best; and the soft tissue measurements for only four years.

'40, Stuart and Dwindell '42, Stuart and Sobel '46, Reynolds '51). The circumstances under which these examinations were performed made it necessary, however, to use simple methods. The data for normal individuals were collected during office hours on children who came for periodic health examinations. Pathologic cases were examined in hospitals, where we had to bring our equipment with us. In both cases examinations had to be made with as little disturbance as possible in office or hospital routine, and with limited equipment. The anthropometric caliper was used for other measurements anyhow; X-ray studies would not have been feasible, and the special calipers were not available. The material presented in this paper may prove, however, that our findings fit well into those obtained by other research workers who could apply more refined methods. We believe that our method allows an analysis of some characteristic features in the distribution of subcutaneous soft tissues, as part of a developmental appraisal, in a comparatively simple manner.

MATERIAL AND METHODS

Our standard values were derived from normal healthy white children, living in metropolitan and suburban New Jersey, predominantly of middle class families. The racial background was not homogeneous: about ⅔ of the children were of Jewish descent, the remaining of Anglo-Saxon, German, Scandinavian, or Slavic origin. It could be shown, however, that body build and physical development of these children did not differ essentially from that of other groups, which are assumed to be typical for the average white population in the United States (Kornfeld '54).

Measurements on skinfolds were taken in the following areas: on the chest about one inch below the middle of the right clavicle; on the abdomen about midway between navel and iliac crest; on the back about one inch medial to the inner border of the right scapula. Subcutaneous tissue masses on the cheeks were measured in the following manner: the bizygomatic diameter was determined over the most prominent points of the zygomatic arch without any pressure, so that the surface of the skin was not dented. Then the measurement was repeated at the same spot, while the caliper was pressed gently against the underlying bone. The difference between the two measurements was obtained, indicating the thickness of the compressible or displaceable subcutaneous masses.

FINDINGS

Mean values of the soft tissue measurements, as obtained by the examination of normal healthy children, are reported in table 1a-d. This table contains also the numbers of children examined in each age group, the medians, the range of variation, and the standard deviations. Figure 1 presents the average values for boys and girls with the omission—for economy of space—of alternating age groups.

TABLE 1

Mean values, medians, range of variations and standard deviations for soft tissue measurements in boys and girls

A. CHEEKS

AGE	BOYS N	Mean	Med.	Min.	Max.	S.D.	GIRLS N	Mean	Med.	Min.	Max.	S.D.
Newborn	50	7.7	7.5	5	12	1.9	50	8.6	8.3	5	13	1.9
3 months	50	9.4	9.7	5	13	2.0	60	9.5	9.5	6	15	1.8
6 "	50	10.1	10.1	5	14	1.9	60	10.1	10.0	6	10	1.8
9 "	40	10.4	10.1	7	15	1.8	50	10.2	10.2	7	15	1.3
12 "	40	9.9	9.9	5	16	2.1	40	9.8	10.1	6	14	1.9
18 "	18	10.0	9.9	7	14	1.6	14	10.8	11.0	7	13	1.6
2 years	40	9.5	9.5	6	13	1.6	30	9.2	9.3	5	12	1.6
2½ "	30	9.5	9.4	6	14	1.7	20	8.4	8.5	5	11	1.6
3 "	50	9.1	9.0	5	14	1.9	45	9.0	9.0	6	12	1.5
3½ "	40	8.7	8.5	6	12	1.4	35	8.7	8.9	5	12	1.7
4 "	50	8.3	8.2	5	13	1.6	50	8.2	8.0	5	11	1.6
4½ "	40	8.0	7.8	5	13	1.7	30	8.2	8.3	4	13	2.1
5 "	50	7.6	7.8	5	12	1.6	50	8.0	8.0	3	12	2.0
5½ "	40	7.7	7.5	5	12	1.8	30	7.5	7.2	5	11	1.6
6 "	50	7.6	7.4	5	13	2.0	45	7.4	7.0	4	12	1.9
6½ "	40	7.7	7.5	5	12	1.7	40	7.2	7.0	4	11	1.6
7 "	40	7.4	7.3	5	10	1.3	50	7.4	7.2	4	12	2.0
7½ "	30	7.4	7.5	5	11	1.6	40	7.3	7.0	4	14	2.1
8 "	36	7.4	7.5	3	10	1.5	48	7.2	6.7	4	11	1.8
8½ "	30	7.6	7.5	5	10	1.4	30	7.2	7.3	4	11	1.6
9 "	30	7.2	7.1	5	11	1.4	49	7.5	7.6	3	13	2.1
9½ "	30	6.8	6.7	5	11	1.4	36	7.4	7.3	4	13	2.1
10 "	40	6.9	6.7	3	11	1.7	40	6.7	6.7	4	13	1.9
10½ "	35	6.5	6.5	4	9	1.1	29	6.5	6.8	3	11	1.9
11 "	30	6.8	6.8	4	10	1.7	30	6.9	6.8	5	11	1.3
11½ "	30	7.1	6.7	5	12	1.6	18	6.9	6.5	4	11	2.1
12 "	30	6.7	6.6	4	11	1.7	18	6.3	6.2	4	9	1.1
12½ "	26	7.4	7.2	5	12	1.5	14	6.9	7.1	4	11	1.7
13 "	23	7.0	6.3	5	11	1.8	12	6.7	6.2	5	9	1.5
13½ "	14	6.4	6.2	4	10	1.6	10	6.5	6.5	5	9	1.4
14 "	15	6.5	6.7	4	9	1.4	4	6.5	6.0	5	9	—
14½ "	7	5.3	5.0	3	7	—						
15 "	10	6.0	6.0	4	8	—						
15½ "	5	5.0	4.7	4	7	—						
Total	1139						1077					

TABLE 1 (Continued)

B. CHEST

AGE	BOYS					GIRLS				
	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.9	3.7	3	7	1.0	4.0	3.9	3	6	0.8
3 months	6.7	6.4	3	12	2.0	7.0	6.3	3	14	2.3
6 "	6.3	5.1	4	10	1.6	7.4	7.1	3	15	2.5
9 "	6.0	5.5	4	9	1.5	6.2	5.9	4	12	1.8
12 "	5.5	5.2	3	9	1.4	6.0	5.7	4	11	1.7
18 "	5.9	5.8	3	10	2.0	6.2	6.0	4	9	1.6
2 years	6.2	6.0	3	10	1.7	6.6	6.5	4	11	1.9
2½ "	6.2	6.0	3	10	2.2	7.0	6.7	4	12	2.2
3 "	6.3	6.2	3	11	1.8	7.7	7.5	4	15	2.3
3½ "	6.0	5.9	4	9	1.5	7.5	7.1	3	16	2.2
4 "	5.9	5.8	2	11	1.8	7.2	6.6	3	14	2.6
4½ "	5.4	4.9	3	9	1.5	7.2	6.2	3	22	3.9
5 "	5.8	5.1	3	15	2.4	7.3	6.7	3	18	2.9
5½ "	6.5	5.2	3	20	3.5	6.9	6.5	3	16	2.8
6 "	6.3	5.1	3	19	3.5	7.7	6.5	3	26	3.0
6½ "	6.5	5.2	3	23	3.9	8.0	6.7	4	18	3.7
7 "	5.9	5.1	3	18	3.2	8.1	7.2	3	21	3.4
7½ "	6.1	4.9	3	19	2.3	8.9	7.8	4	22	4.2
8 "	6.2	5.1	3	24	2.9	8.8	7.7	3	20	3.9
8½ "	7.1	5.3	3	24	4.5	9.3	8.5	4	17	3.6
9 "	7.0	5.4	3	19	4.0	10.4	8.9	3	28	5.1
9½ "	7.6	6.2	2	20	4.3	10.9	11.0	4	20	4.7
10 "	7.5	6.0	3	20	4.4	10.2	9.0	4	23	5.0
10½ "	8.1	6.0	3	28	5.7	11.0	8.6	4	22	5.4
11 "	7.8	6.0	3	19	4.4	10.6	8.4	5	28	4.9
11½ "	9.7	7.0	3	15	6.5	9.5	9.0	4	18	3.6
12 "	9.9	8.0	4	25	5.9	10.2	8.8	5	18	3.9
12½ "	10.0	8.5	3	20	5.5	9.4	9.0	5	18	3.7
13 "	9.1	6.8	3	25	5.6	11.2	10.5	6	19	4.0
13½ "	7.6	6.7	4	16	3.8	10.6	10.5	5	15	2.9
14 "	8.3	5.3	4	20	5.2	10.2	9.5	7	15	—
14½ "	6.9	5.7	4	16	—					
15 "	7.5	5.5	4	15	—					
15½ "	6.0	6.0	5	7	—					

TABLE 1 (Continued)

	C. Abdomen									
	BOYS					GIRLS				
AGE	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.2	3.1	2	5	0.6	3.1	3.1	2	4	0.4
3 months	5.6	5.5	3	8	1.3	6.4	6.4	3	10	2.5
6 "	5.3	4.9	3	9	1.5	6.1	5.9	3	10	1.8
9 "	5.1	4.7	3	9	1.4	5.5	5.1	3	10	1.4
12 "	4.8	4.7	3	9	1.4	5.4	5.2	3	9	1.3
18 "	4.8	4.4	3	8	1.4	4.8	4.8	3	6	0.9
2 years	4.7	4.7	3	7	1.2	5.0	4.9	2	8	1.4
2½ "	4.2	4.2	3	6	0.9	5.2	5.2	3	8	1.6
3 "	4.3	4.1	3	8	1.2	5.4	5.0	3	11	1.7
3½ "	4.4	4.1	3	9	1.4	5.1	4.6	3	10	1.8
4 "	4.0	3.9	2	7	1.0	4.8	4.3	3	10	1.8
4½ "	4.0	3.8	3	8	1.2	5.5	4.1	3	25	4.3
5 "	4.6	3.9	2	9	1.4	5.3	4.0	2	20	3.0
5½ "	4.5	4.1	2	10	1.9	5.1	4.3	3	12	2.3
6 "	4.6	3.8	3	18	2.5	5.6	4.5	3	14	2.7
6½ "	4.9	3.7	2	22	3.9	6.0	5.1	4	11	2.4
7 "	4.2	3.8	3	13	1.8	6.1	5.3	2	15	2.8
7½ "	3.9	3.5	2	9	1.5	7.4	6.1	2	22	4.0
8 "	4.5	4.0	3	11	1.8	7.5	6.0	3	18	4.1
8½ "	4.6	4.0	3	13	2.1	8.7	7.5	3	20	4.5
9 "	5.2	3.9	3	17	3.4	9.3	8.3	3	25	5.2
9½ "	5.6	4.4	2	14	3.2	9.7	8.0	3	21	5.7
10 "	5.4	4.6	2	14	2.9	9.3	8.5	3	20	4.8
10½ "	6.8	4.8	2	27	5.3	8.0	8.0	4	32	6.2
11 "	6.2	4.7	3	15	3.7	10.1	8.0	3	28	5.8
11½ "	7.8	6.0	3	20	5.0	9.9	8.2	4	20	4.7
12 "	7.8	6.5	3	19	4.5	11.4	10.0	5	21	4.9
12½ "	8.7	5.8	3	24	5.7	10.5	9.8	4	18	3.8
13 "	8.8	5.4	3	24	5.8	12.8	12.5	5	22	5.7
13½ "	6.9	5.2	3	16	4.0	13.4	13.7	8	22	4.4
14 "	9.8	6.0	3	28	7.2	15.2	15.5	12	18	—
14½ "	8.0	6.0	3	20	—					
15 "	9.9	6.0	4	21	—	—	—	—	—	—
15½ "	7.6	7.0	5	12	—	—	—	—	—	—

TABLE 1 (Continued)

D. BACK

AGE	BOYS					GIRLS				
	Mean	Med.	Min.	Max.	S.D.	Mean	Med.	Min.	Max.	S.D.
Newborn	3.8	3.7	3	7	0.8	4.1	4.1	3	5	0.7
3 months	5.7	5.6	4	10	1.1	6.1	6.0	4	10	1.5
6 "	5.9	5.6	4	10	1.2	6.4	6.0	3	10	1.5
9 "	6.3	6.0	4	9	1.3	6.6	6.8	4	9	1.6
12 "	6.4	6.3	4	10	1.3	6.8	6.8	4	10	1.6
18 "	7.2	7.3	5	9	1.3	7.1	6.7	5	10	1.5
2 years	6.0	5.7	3	9	1.5	6.3	5.9	4	11	1.9
2½ "	5.9	5.8	4	9	1.4	6.4	5.7	4	12	2.0
3 "	5.8	5.7	3	10	1.5	6.4	6.2	4	12	1.6
3½ "	5.4	5.3	3	9	1.2	5.8	5.7	3	9	1.3
4 "	5.4	5.3	3	9	1.3	5.9	5.3	3	13	1.8
4½ "	5.1	4.9	3	9	1.3	6.2	5.2	3	17	2.8
5 "	5.3	5.0	3	9	1.5	6.2	5.7	3	15	1.9
5½ "	5.7	5.1	3	12	1.9	6.1	5.7	4	12	1.7
6 "	5.5	5.0	3	12	2.3	5.9	5.3	3	13	2.0
6½ "	6.1	5.4	3	14	2.4	6.1	5.5	4	12	2.1
7 "	5.5	5.0	4	12	1.4	6.3	5.7	3	15	2.3
7½ "	5.1	4.9	3	10	1.4	6.6	5.4	3	16	2.9
8 "	5.5	5.1	4	9	1.4	6.3	5.3	4	15	2.5
8½ "	5.5	5.1	4	12	1.8	6.9	6.5	4	11	1.9
9 "	5.6	5.2	4	12	1.9	7.1	6.5	4	23	3.4
9½ "	5.7	5.4	3	11	1.8	7.7	7.0	4	18	2.8
10 "	5.7	5.2	3	10	1.7	6.6	6.2	4	13	1.9
10½ "	6.0	5.1	3	20	3.0	7.2	6.4	4	15	2.5
11 "	5.8	5.7	4	12	1.7	7.2	6.5	4	14	2.8
11½ "	6.1	5.6	4	13	2.0	7.2	7.5	5	9	1.3
12 "	7.0	6.2	4	13	2.3	7.6	7.3	4	14	2.4
12½ "	7.0	6.2	4	16	2.8	7.6	7.7	5	10	1.1
13 "	7.5	6.3	4	17	3.3	8.2	8.0	5	12	2.0
13½ "	6.5	6.1	4	11	1.8	8.5	8.2	7	12	1.5
14 "	7.1	5.4	4	12	2.7	9.5	9.5	9	10	—
14½ "	7.1	6.7	4	13	—					
15 "	6.9	6.2	5	13	—	—	—	—	—	—
15½ "	7.0	7.3	5	8	—	—	—	—	—	—

Analysis of the figures in these tables reaffirms earlier reports in many points. (For a review of the earlier literature see Reynolds '51). Higher mean values for girls were found in the chest measurements in all age groups with the exception only of the 11½ and 12½ year olds; on the abdomen in all age groups except the newborn and the 18 month olds, where the measurements were equal or nearly equal in both sexes; on the back in all age groups except for the 18 month and 6½ year olds, where again the measurements were equal or almost equal. The preponderance of the mean values in the females was least regular in the cheeks, where higher means in boys were found for the age groups of 2½, 6½, 8½, 12, 12½, and 13 years and equal or almost equal mean values in several other age groups.

The difference between the soft tissue measurements in boys and girls which are seen in the mean values for each age group are even more evident if we analyse the distribution of the individual measurements in each age group. For reason of economy of space we do not include tables of these distributions in this publication. We would like to mention, however, that such distribution tables explain some of the irregularities seen in the tabulation of the mean values. The highly asymmetric distribution of the individual measurements, which is most evident in these distribution tables, is a well known phenomenon. Minus variants may extend from the mean to a low value representing the thickness of the skin itself with a minimum of subcutaneous tissue; plus variants may extend into extremely high values with execessive fat accumulation. This skewed character of the distribution of soft tissue measurements can also be seen in the difference between the means and the medians. The medians may be considered as even more representative for the typical changes in soft tissue distribution during childhood than the means.

There are also differences in the variability of the soft tissue measurements between boys and girls. These differences are evident when we compare the standard deviations or, even better, when the coefficient of variation (100 times the standard deviation divided by the mean) is used for comparison. In the newborn the variability appears to be slightly higher in boys than in girls for all four measurements. The variability for the cheeks stays slightly higher in boys during the first year; during the second and third year there is no steady difference; from the fifth to the 13th year the variability is higher in girls, during the 14th year higher in boys. The variability of the chest tissues is slightly higher in girls of 6 to 12 months, markedly higher in boys

from the 6th year up to the age of 14. Variability of the abdominal fat masses is higher in girls from two to 8 years, in boys from 9 to 14. Variability of the skinfolds on the back is higher in girls in most age groups until 11 years, higher in boys from 12 to 14.

Changes in the distribution of soft tissue masses during childhood have been described since the first studies of skinfold measurements in children were published. Neuman ('12) reported the faster increase in abdominal fat in girls. He also tried to find quantitative relations between changes in skinfold thickness and changes in body weight, as Oeder ('10) had done for adults. Batkin ('15) described typical differences in skinfold thickness for 8 different regions but assumed from his findings a rather persistent pattern for these regional differences throughout childhood. Peiser ('21) compared the findings on skinfolds and their changes with the individual Pelidisi Index (Pirquet's index for the nutritional state). In our studies in Vienna the different character of the average curves for the soft tissue in the four regions was demonstrated. The most exhaustive study of this topic is Reynolds' monograph ('51), in which a thorough discussion of all earlier research in this field may also be found.

In our present studies on New Jersey children the following changes were found to be typical: mean values for the soft tissue masses in all four regions increase rapidly during the first 6 months of life, in boys as well as in girls. The mean values for the cheeks stay high until about 18 months and decrease slowly thereafter. Mean values for chest decrease slightly at the end of infancy, stay low from one to 5 years, then increase to reach the highest values in boys at 11-13 years, in girls at 9-14 years. After 14 years mean values decrease in both sexes. Medians for the chest show a second (pre-puberty) increase in boys from 11-13, in girls from 9-14 years. Mean values for abdomen stay low in boys from one to 9 years, in girls from one to 7 years, after which period an increase takes place faster in girls, slower and less markedly in boys. Changes in the soft tissue masses on the back are similar to those on the abdomen but less pronounced.

The described changes show a specific pattern of development for each of the four measurements. The difference in these developmental patterns results in typical changes in the relation between the measurements taken in the four different regions. These changes can be illustrated by graphs based upon the mean values for the different age groups, as shown in Figure 1. The following typical changes can be read from

these graphs: at birth the mean value for cheeks is by far the highest, the value for abdomen the lowest; the values for chest and back are in between, near to each other and only slightly above the mean for abdomen. These relations stay rather similar through the first two or three years of life in boys as well as in girls. The whole level of the graphs reflects the increase of the soft tissue masses during the first months of life and the following slow decrease during the second, third and fourth year. Around an age of 5-7 years the profiles as a whole reach the lowest level; at the same time means for the skinfold measurements

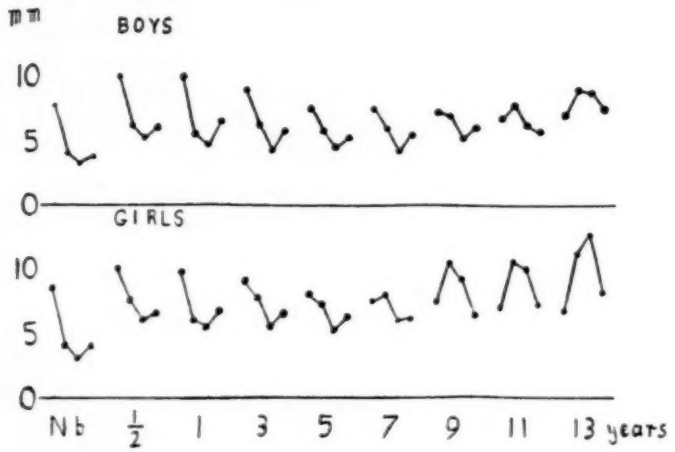

FIG. 1. AVERAGE CHANGES FROM THE NEWBORN TO THE AGE OF 13 YEARS. LINES CONNECT DOTS REPRESENTING SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK, IN THAT ORDER.

become nearer to the level of the cheek measurements, which are decreasing. From 6 to 10 years there is a difference in these soft tissue profiles between boys and girls: the girls show a very definite pattern with the chest values becoming more and more elevated; the values for abdominal fat follow with a slightly slower increase, means for cheeks and back lagging behind. At 12-14 years the means for abdominal soft tissue masses surpass the values for the chest, thus climbing to the top of the profile. The relation between the two lower values, cheeks and back, changes so that finally the cheeks have the lowest mean value with the back tissue gradually increasing. In boys the changes are slightly different: The means for chest surpass the means for the cheeks later and more slowly than in girls. The increase in abdominal tissue masses

is also delayed and brings the mean values for abdomen above those for the chest in boys only at 14 years.

Similar changes as depicted in these profiles based upon mean values for each age group can be demonstrated in series of graphs based upon longitudinal studies on individuals. Figure 2 gives examples for two infants, observed from birth to the age of three years. We see in both children increase of the soft tissue masses during the first and decrease during the second year. At the same time we notice how certain indi-

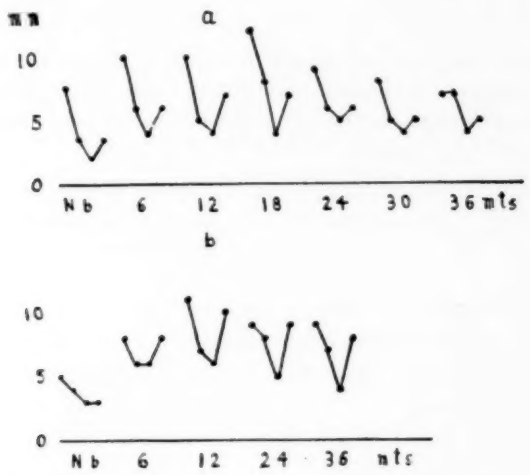

FIG. 2. a AND b. INDIVIDUAL CHANGES IN TWO INFANTS OBSERVED THROUGH THE FIRST THREE YEARS OF LIFE: SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK.

vidual features of the soft tissue distribution are rather persistent: high values of the cheek tissue in the one case (figure 2a), comparatively high values of the back tissue in the second case (figure 2b). Unusually high values for the cheeks may persist longer, as shown in figure 3a for a boy at the ages from two to 5 years. By contrast figure 3b depicts the condition in a girl with persistently high values for chest tissue, gradual increase of all soft tissue masses from $2\frac{1}{2}$ to 4 years (moderate obesity), and slimming in the fifth year. Figure 4a shows gradual decrease of soft tissue masses in a girl during the 5th and 6th year, with a sudden increase of fat on the chest in the 7th year. A similar increase of subcutaneous tissue during the 6th, 7th and 8th year, fol-

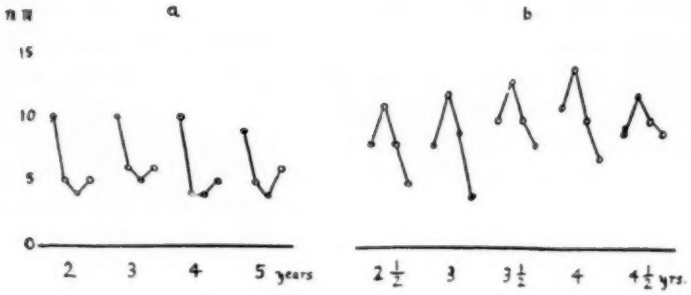

FIG. 3. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. BOY WHO SHOWS UNUSUALLY HIGH VALUES FOR THE CHEEKS AT THE AGES OF 2, 3, 4 AND 5 YEARS. b. GIRL WITH PERSISTENT HIGH VALUES FOR CHEST; MODERATE OBESITY DEVELOPING DURING FOURTH YEAR.

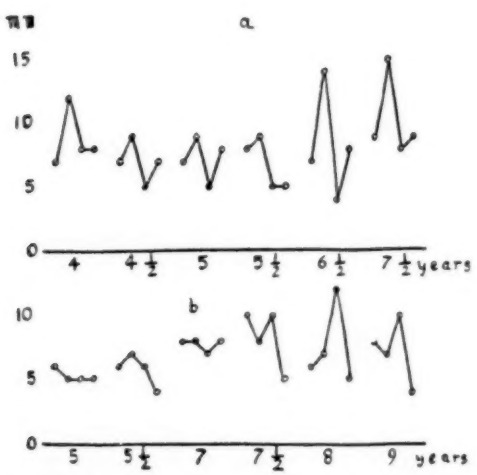

FIG. 4. SOFT TISSUE MASSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. GIRL WITH DECREASES IN ALL MASSES DURING THE FIFTH YEAR AND AN INCREASE IN CHEST FAT IN THE SEVENTH AND EIGHTH YEAR OF LIFE. b. GIRL WITH INCREASES FROM 5 TO 8 YEARS AND SLIGHT DECREASE AT 9 YEARS.

lowed by a slight decrease during the 9th year in shown for another girl in figure 4b. Persistent slenderness through age 9½ to 13½ is shown for a boy in figure 5a, while figure 5b depicts the conditions in a girl

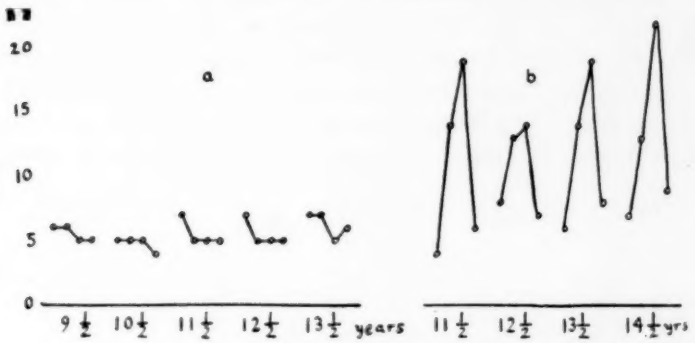

FIG. 5. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. a. BOY, PERSISTENTLY SLENDER FROM 9½ TO 13½ YEARS. b. OBESE GIRL WITH TRANSITORY SLIMMING DURING 13TH YEAR.

from 11½ to 14½ years. A transitory decrease of the soft tissue masses during the 13th year interrupts here an otherwise rather persistent pattern of moderate obesity. Figure 6 ilustrates the case of a boy with a similar transitory period of comparative slenderness around the age of 12 years interrupting an otherwise steady increase of the soft tissue

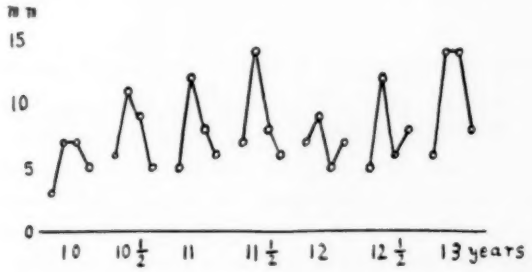

FIG. 6. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK. BOY WITH MODERATE INCREASES IN FAT FROM 10 TO 11½ YEARS FOLLOWED BY PREPUBERTAL SLIMMING AND INCREASES AGAIN DURING THE 13TH YEAR.

masses from age 10 to age 13. Figure 7 shows the development of the soft tissue masses in a pair of identical twins for the period from 8 to 10 years. The figure consists of 5 pairs of graphs: the first graph in each

pair depicts the measurements of the one twin, while the second graph of each pair depicts the measurements of the other twin, obtained at the same time. The graphs illustrate the similarity of the profiles for the two twins in general and at the same time show some persistent individual features in minor details in which the twins differ.

All these changes become even more meaningful when the development of the soft tissue masses is compared with other measuremnts, taken at the same time. To illustrate this, figure 8 shows two cases of moderate obesity and table 2 contains excerpts of the anthropometric findings for

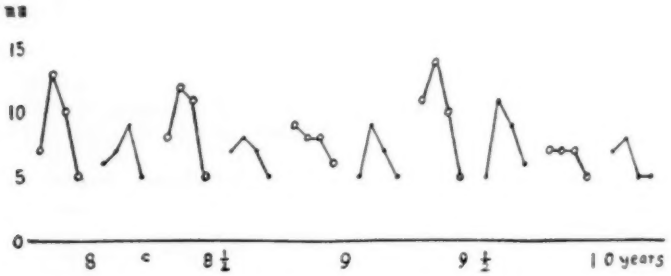

FIG. 7. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK IN A PAIR OF IDENTICAL TWINS. FOR EACH AGE FROM 8 TO 10 YEARS THE GRAPH WITH OPEN CIRCLES DEPICTS THE CONDITION FOUND IN ONE TWIN (BARBARA), THE SECOND GRAPH, WITH DOTS, DEPICTS THAT IN THE OTHER (BEVERLY). BEVERLY IS SLIGHTLY THINNER THROUGHOUT THESE YEARS; THE TREND OF CHANGES FROM YEAR TO YEAR, HOWEVER, SHOWS GREAT SIMILARITIES FOR BOTH GIRLS.

the same period. The first case is that of a boy who gained very rapidly during the second half of the 9th and during the second half of the 11th year. During these two periods of rapid weight gain arm circumference and abdominal tissue show rapid increases, tissues on cheeks and back slight increase, while the measurements on the chest behave somewhat paradoxically, decreasing just during the periods of fast weight gain and increasing during periods of considerably slower weight gain. In the second case (figure 8b and table 2b) we find a boy with longitudinal growth steadily above average for his age, weight persistently above average for his height, arm circumference persistently high above average, and wrist circumference moderately high. The measurements of superficial soft tissue masses, however, show persistently average values in the cheeks, and moderately elevated values for the back. Thickness of the skinfolds on the chest was very high at 9½ and 11 years, but came

down to moderate elevated values in the 13th and 14th years. Skinfolds on the back were moderately high at 9½ and 11 years, increased considerably at 12½ years, after which they decreased in thickness so far that, at 14 years, an average level was reached. Analysis of the changes

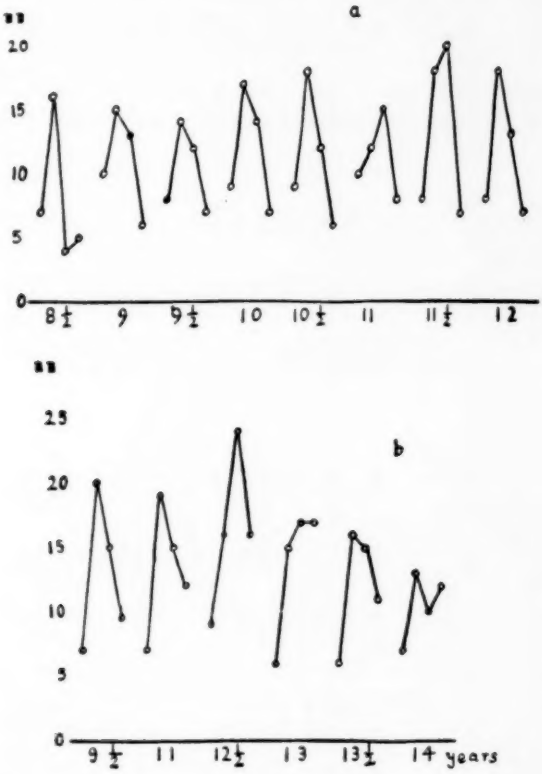

FIG. 8. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK IN TWO CASES OF OBESITY IN BOYS. SOME ADDITIONAL ANTHROPOMETRIC DATA ARE REPORTED IN TABLE 2.

in the soft tissue distribution by observations of this kind may be helpful in the management of obesity.

In a similar way such studies may help in the evaluation of the development of premature infants. Such infants show, at least in the beginning, a marked deficiency in soft tissue development. It is interesting to see how this deficiency in soft tissue development is corrected and to compare this improvement with other features of the physical develop-

TABLE 2

Some measurements obtained in repeated examinations on 2 boys with moderate obesity

AGE	BODY LENGTH		WEIGHT			WRIST			ARM			SOFT TISSUE THICKNESS			
		Average for Age		Average for Age	Average for Height		Average for Age	Average for Height		Average for Age	Average for Height				
years	cm	cm	kg	kg	kg	mm	mm	mm	mm	mm	mm	Cheek mm	Chest mm	Abd. mm	Back mm
a) Steven H.															
8½	128.5	132.0	31.5	28.70	27.0	134	130	128	223	191	187	7	16	4	5
9	131.5	134.5	34.25	30.30	28.50	140	131	130	238	196	190	10	15	12	6
9½	133.5	137.0	34.45	32.00	29.80	140	133	131	235	201	194	8	14	12	7
10	135.0	139.0	35.30	33.70	30.60	143	135	131	235	205	197	9	17	14	7
10½	137.5	141.5	36.30	35.50	32.00	143	137	133	235	210	203	9	18	12	6
11	141.0	144.0	41.40	37.40	35.20	145	139	137	270	215	209	10	12	15	8
11½	143.0	146.5	42.40	39.50	36.65	147	141	139	265	220	214	8	18	20	7
12	146.0	149.5	41.70	41.75	39.05	147	143	141	258	225	220	9	18	13	7
b) Paul A.															
9½	144.0	136.5	44.85	32.00	37.40	145	133	139	236	201	215	7	20	14	9
11	153.0	144.0	55.50	37.40	44.35	155	139	146	285	215	226	7	19	15	12
12½	161.0	152.0	62.25	43.60	50.65	157	145	152	285	228	235	9	16	24	16
13	164.0	156.0	68.85	46.50	53.00	165	149	155	300	232	237	6	15	17	17
13½	168.5	159.5	68.00	49.30	56.40	165	150	159	290	234	240	6	16	15	11
14	172.5	162.5	71.60	52.50	60.80	167	154	165	305	236	250	7	13	10	12

ment in prematurely born infants. The status of the soft tissue masses in two premature infants from the age of one month up to two years is illustrated in figure 9a and b. Some additional anthropometric data are reported in Table 3.

Melanie R. (figure 9a and table 3a), first child of a diabetic mother, who had one spontaneous abortion before, was delivered after about 35 weeks of an uneventful pregnancy by cesarean section, with a birth weight of 3 lbs. 3 oz. (1450 grams). She was discharged from the hospital at four weeks of age in good general conditions with a weight

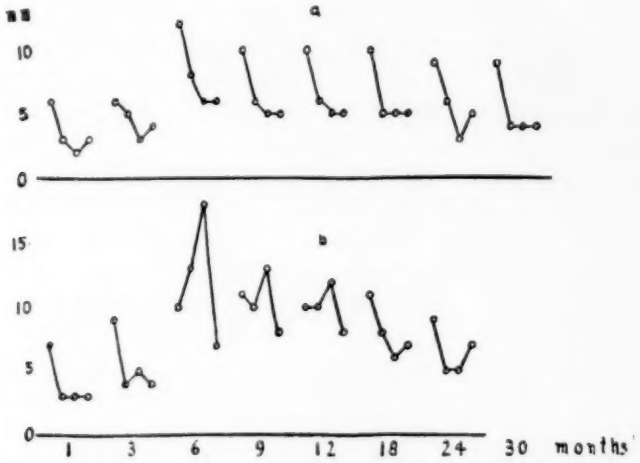

FIG. 9. SOFT TISSUE THICKNESSES ON CHEEKS, CHEST, ABDOMEN AND BACK IN TWO INFANTS BORN PREMATURELY. SOME ADDITIONAL ANTHROPOMETRIC DATA ARE REPORTED IN TABLE 3.

of 1700 grams and body length of 43 cm. Soft tissue on the cheeks was slightly below average, skinfolds on chest, abdomen and back very low. At about two months she had reached the average body length and weight of a normal full term newborn girl. Longitudinal growth progressed steadily, but stayed below the average for the age. Body weight increased rapidly, was soon above average for the child's body length and starting with 9 months even above the average of girls of her age. Circumference of the wrist reached the average for age at 9 months and then stayed near the average values. The arm circumference increased in a similar way as the wrist. All soft tissue measurements were still below average at three months, cheeks only slightly, the three skinfolds

TABLE 3

Some measurement obtained in repeated examinations of 2 premature infants

AGE	BODY LENGTH		WEIGHT			WRIST			ARM			SOFT TISSUE THICKNESS			
		Average for		Average for			Average for			Average for					
months	cm	Age cm	kg	Age kg	Height kg	mm	Age mm	Height mm	mm	Age mm	Height mm	Cheek mm	Chest mm	Abd. mm	Back mm
a) Melanie R.															
1	43.0	52.5	1.70	3.80	2.00	54	76	—	63	100	—	7	2.5	2.5	2.5
3	51.0	59.5	3.50	5.60	3.50	69	86	73	84	119	90	9	4	5	4
6	60.0	66.0	6.90	7.50	5.75	90	95	86	120	136	113	10	13	18	7
9	67.5	70.0	9.10	8.60	7.95	100	100	96	140	144	133	11	10	13	8
12	72.0	74.0	10.90	9.70	9.20	107	102	101	150	148	141	10	10	12	8
18	78.0	80.5	12.50	11.10	10.60	103	103	102	165	151	146	11	8	6	7
24	82.5	86.0	12.60	12.25	11.90	105	104	103	152	153	151	9	5	5	7
b) John S.															
1	42.5	53.5	1.75	4.05	2.00	57	79	—	61	97	—	6	3	2	3
3	50.5	60.5	3.60	6.00	3.40	79	90	71	94	119	85	6	5	3	4
6	60.5	67.5	6.40	8.10	6.00	90	100	90	122	136	119	12	8	6	6
9	66.5	71.5	7.70	9.40	7.80	102	105	98	135	144	132	10	6	5	5
12	71.0	75.5	9.10	10.40	9.25	102	107	104	148	148	143	10	6	5	5
18	76.5	82.0	9.85	11.80	10.60	100	108	107	145	151	148	10	5	5	5
24	83.5	87.5	11.10	12.90	12.10	101	109	108	148	153	151	9	6	3	5
30	88.5	92.0	11.80	13.85	13.10	102	110	109	143	155	153	9	4	4	4

considerably. From 6 to 24 months we find near average values for cheeks and back. Skinfolds on chest and abdomen were considerably above average at 6-12 months, nearly average at 18 and 24 months.

John S. (figure 9b and table 4b) was delivered 8 weeks before term, by cesarean section because of premature separation of the placenta, with a birth weight of 3 lbs 9½ oz. (1600 grams). At 10 days his weight was down to 1360 grams. At the age of one month his weight of 1750 grams was approximately average for his body length of 42.5 cm. and this relation stayed about the same until the age of 12 months. After the first year the weight increased much more slowly, so that we find a persistent underweight for his height from 18 to 30 months, and a body length below the average for his age all through this time. Corresponding to this underweight we see the wrist and arm circumferences steadily below average, with the exception of an average value for the arm circumference at the age of 12 months. At the age of one month and again at the age of three months all soft tissue measurements were considerably below average. At 6 months, however, the figures for cheeks and chest were above average, the figures for abdomen and back around average. After this period the values for cheeks, chest and abdomen stayed around the average, the skinfolds on the back slightly below average.

Analysis of the soft tissue development in these two prematurely born infants shows the initial underdevelopment of the soft tissue masses corrected by about 6 months. While other features of delayed physical development may persist longer, the pattern of soft tissue distribution after the 6th month shows no after effect of the original deficiency. Individual differences, based apparently upon genetic factors, show up in the soft tissue profiles of prematurely born infants after the 6th month just as they appear in full term infants.

DISCUSSION

The studies reported here present a comparatively simple method for the evaluation of the soft tissue distribution in children of different age groups. Some changes in this distribution are characteristic for the normal development of the average child, with variations occurring within a normal range. Other more marked variations occur in borderline cases of normality, as in prematurity or in moderate obesity. Still more pronounced deviations have been observed in pathologic conditions; the discussion of such cases, however, was not included in this paper.

The method described here had been developed during studies on children in Vienna. It was used there to analyse the effect on the nutritional status of open air treatment in children with inactive tuberculosis (Kornfeld and Schüller, '31) and also to follow the changes in the status of such children after discontinuation of such treatment (Kornfeld and Orosz, '31). These studies revealed that the considerable weight gain in such periods and the loss of weight usually following such accelerated gain is accompanied by changes in the soft tissue distribution, but that these changes show considerable individual variations.

The significance of individual differences in the soft tissue distribution in children has been discussed by Reynolds ('51) on the basis of roentgenometric studies on children of the Fels Institute Research Project. Among his examples of individual peculiarities are also two pairs of twins and three cases of obesity. Fat distribution in children with pathologic disturbances other than obesity has not been studied extensively. Exceptions were the studies of two cases with lipodystrophy by Feer ('15) and a paper by Batkin ('15) who described changes in skinfold measurements in different pathologic conditions.

The role of relative fat patterns as an individual characteristic has been analysed recently in adults by Garn ('55a). Roentgenometric measurements of fat thickness in 9 different areas were converted into standard score values. On this basis profiles of the fat distribution were drawn, which show very definite individual characteristics. Garn shows that these individual fat patterns are of a considerable consistency even through periods of enforced weight loss. A similar deduction may be obtained from our graphs for normal as well as for obese children and also from our earlier observations on children during and after open air treatment. In a more recent paper Garn ('55b) emphasizes the advantage of relative patterns based upon standard scores, as compared with profiles based upon absolute measurements. We used similar profiles, based upon variation classes of selected measurements, for the graphic illustration of body build and physical development in earlier studies (Kornfeld '27 and '28). We hesitated, however, to use classification by standard deviations in the construction of profiles for the soft tissue distribution because of the highly asymmetric distribution of the individual values.

SUMMARY

1. A method of evaluation and graphic illustration of the soft tissue distribution in children is described. It can be used comparatively easily within a general anthropometric examination. The method comprises skinfold measurements on chest, abdomen and back, and measurements of the compressible soft tissue on the cheeks.

2. Mean values, medians, standard deviations, and range of variations are reported and discussed.

3. General trends of changes in the distribution of soft tissue masses during childhood as well as examples of individual deviations from these general trends are illustrated.

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APPLICATION OF THE GOMPERTZ CURVE TO THE OBSERVED PATTERN OF GROWTH IN LENGTH OF 48 INDIVIDUAL BOYS AND GIRLS DURING THE ADOLESCENT CYCLE OF GROWTH

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INTRODUCTION

THE longitudinal study of the physical growth of children from birth to maturity, which is being carried on by the Child Research Council, offers a fund of valuable data for the fitting of calculated growth curves to the observed pattern of growth of these boys and girls. The present paper deals with the 48 calculated curves which have been fitted to a portion of the observed pattern of growth in length of 48 boys and girls from the Child Research Council series.

The general pattern which is formed by the successive observed measurements of length, from birth to young adult life, of any one of these boys or girls is the pattern illustrated by fig. 1. During infancy and early childhood the pattern is a continually decelerating curve, which flattens out during the later childhood years to what is essentially a sloping straight line. Then, at a point somewhere near the time when the first outward sign of beginning secondary sex development is observed in the boy or girl, there is a sudden and dramatic change in the growth pattern. It now follows a course shaped somewhat like the letter *S*, with a sharp acceleration of the rate of growth for a time, followed in turn by a period of deceleration, and finally approaches a horizontal level as the adult length of the individual is attained.

Our separate treatment of the later *S*-shaped portion of the growth pattern, without attempting to find some mathematical equation which

might be manipulated in such a way as to cover the entire growth period from birth to maturity, seems to us to need no apology. In the first place, the period from birth to maturity is itself only a portion of a larger growth pattern which has its beginning at conception of the

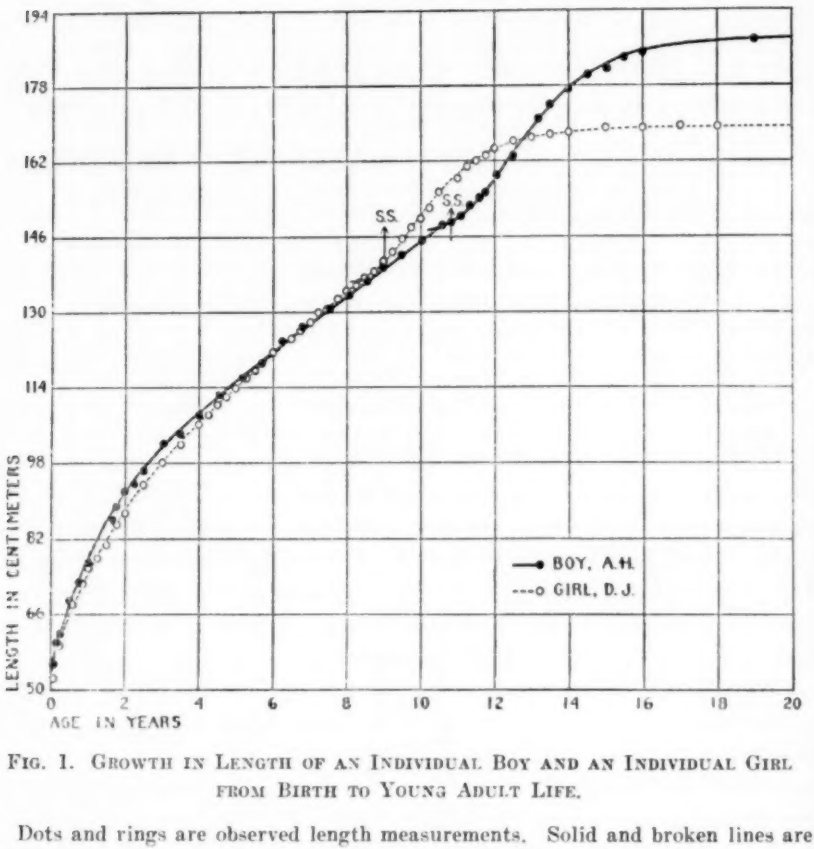


FIG. 1. GROWTH IN LENGTH OF AN INDIVIDUAL BOY AND AN INDIVIDUAL GIRL FROM BIRTH TO YOUNG ADULT LIFE.

Dots and rings are observed length measurements. Solid and broken lines are the calculated growth curves—equation of Jenss and Bayley for the early years, Gompertz equation for the *S*-shaped adolescent cycle.

SS marks first recorded sign of secondary sex development.

individual, and which we can never know in its entirety. And in the second place, the *S*-shaped pattern of growth during the transition of the individual from a child to an adult is something so obviously new and different that it seems not only possible but desirable to treat it as a separate cycle of the growth process, which proceeds according to its own peculiar laws.

The concept of cycles of growth has been used by various authors in the field of growth, with somewhat varying definitions of its meaning. A practical definition from the standpoint of the pattern of human growth, as we see it, is the one proposed by Courtis ('37), who defines a cycle of growth as a period of specific maturation during which the elements and forces acting on the growth process are constant, within reasonable limits.

We are not in a position to discuss the hormonal stimuli that are acting, at different times, on the growth of the boys and girls used for this study, because hormone studies have not as yet been done on the boys and girls of the Child Research Council series. But it would be generally conceded that the hormonal stimuli affecting growth are not constant throughout the period from birth to maturity, and that there is a sudden entrance of new and different hormones into the picture at about the time when sexual maturing of the individual begins. We have therefore designated the *S*-shaped portion of the pattern of growth in length, which coincides approximately with the period of sexual maturing, as the "adolescent cycle" of growth in length. The term will be used with this meaning throughout the present paper.

For fitting the pattern of growth in length during infancy and childhood, we have made use, at the Child Research Council, of the growth equation of Jenss and Bayley ('37), which we hope to report in a paper at some later date. For the *S*-shaped adolescent cycle of growth, with which the present paper is concerned, we have used the equation of Benjamin Gompertz (1825), which was originally developed by Gompertz in 1825, in connection with actuarial life tables, and which was much later described as a growth curve applicable to the growth of biological organisms by Winsor ('32), by Courtis ('32), by Backman ('38), and by others.

Our choice of the Gompertz curve is based partly on the empirical finding that the *S*-shaped adolescent growth cycle of individual boys and girls could be fitted very satisfactorily with it; partly because the essential nature of the Gompertz equation (to be described in a later section of this paper) seems to us to be a logical one for describing the process of growth; and partly because the actual calculation involved in fitting the Gompertz curve seems much less laborious, at least when done with the help of the *isochron* table of Courtis ('32), than the calculation of other types of *S*-shaped exponential curves that might conceivably have been used in the same way.

Various types of exponential curves have been fitted satisfactorily by different workers to growth patterns in the form of a single *S*-shaped cycle. Robertson ('23), who believed that all growth is governed by a master chemical reaction, autocatalytic in nature, used the symmetrical logistic (autocatalytic) curve for the growth of certain animals and plants and also applied it to different cycles of human growth in weight (averages from mass data), getting a reasonably good fit for his adolescent cycle in man but apparently less good fits for other portions of the human growth pattern. Pearl ('25) and Pearl and Reed ('25) applied the symmetrical logistic curve to population growth and to certain types of animal and plant growth and also fitted the much more laborious and complicated skewed logistic curve to growth in weight of the rat, from the data of Donaldson, to growth of the pumpkin, from Robertson's data, and to growth in length of the tadpole's tail, from Durbin's data, obtaining very satisfactory fits with this curve. Merrell ('31) applied the symmetrical logistic curve satisfactorily to growth in weight of individual rabbits. Weymouth, McMillin, and Rich ('31) applied the Gompertz curve satisfactorily to growth in length of razor clams and also to Donaldson's data for growth of the rat in weight. Courtis ('32) gives many examples of satisfactory application of the Gompertz curve to growth of various plants and animals and also to mental growth in boys and girls and even to the learning of assigned lessons.

For fitting the observed pattern of the adolescent cycle of growth in length of boys and girls in the Child Research Council series, the Gompertz curve seems the most appropriate curve to use, though we make no argument for it as the only possible one that could describe the growth cycle correctly.

Our fitting of the 48 individual adolescent growth curves has increased our respect, not only for the Gompertz curve as a useful tool for describing growth in length during this age period, but also for the great superiority of longitudinal series of measurements of individuals, in contrast to the averaged measurements of a group of individuals. Fig. 4 is an illustration of the inadequacy of averaged annual measurements of a group of 24 girls as a description of the growth of individual girls from the same group, during the adolescent age period. The great variation in timing of the adolescent cycle, as well as in size at the start of the cycle and in the intensity of growth during the cycle, makes the pattern of the averaged measurements misleading and almost meaningless.

SUBJECTS

The subjects chosen for this study of the pattern of the adolescent growth cycle were 24 boys and 24 girls who had been followed from birth as part of a larger longitudinal study at the Child Research Council. They were selected from the larger group on the basis of being old enough, at the time when the curves were fitted, to have stopped growing in length, according to our measurements, and having a sufficiently complete series of measurements, over the period covered by the fitted curves, to give a clear picture of the pattern of their growth during that period.

The group of 48 boys and girls is a fairly homogeneous one. They are all white and born in the United States. Ancestral extractions, other than American, are from British and North European stock. No Jewish children are in this particular group, and none of Italian or Spanish extraction. Like the larger Child Research Council Series, the group is above average in socio-economic status.

The 48 boys and girls had been measured by anthropometer approximately once in three months, in most cases, until the early "teen" years then once every 6 months until the late "teens," and then once a year.

We fitted the calculated curves to the supine length of these individuals (always somewhat greater than standing height) because we hope to make, at a future date, some comparisons between the pattern of the adolescent growth cycle and the pattern of growth in infancy, when the children are necessarily measured supine. In cases where our older boys and girls had been measured only in the standing position, we corrected the measurement to the corresponding approximate supine length by the formula of Carrol Palmer ('32).

The plotted series of length measurements of each of the 48 boys and girls follows the general pattern of growth that is illustrated by fig. 1. Some, like the boy and girl shown in fig. 1, maintain their late childhood rate of growth consistently until the actual beginning of the *S*-shaped adolescent growth cycle. Others show a more or less noticeable falling off from their previous childhood rate during the last year or two before they get started on the adolescent cycle. In these latter cases, it would seem that the hormonal stimuli which had been responsible for the growth during infancy and childhood must have played out before the new stimuli that would initiate the adolescent growth cycle were ready to begin.

Once actually started on the adolescent growth cycle, the observed length of the 48 boys and girls conforms to the *S*-shaped pattern of the Gompertz curve with great uniformity and consistency. The boy and girl shown in fig. 1, the boy in fig. 2, the girl in fig. 3, and the 4 girls

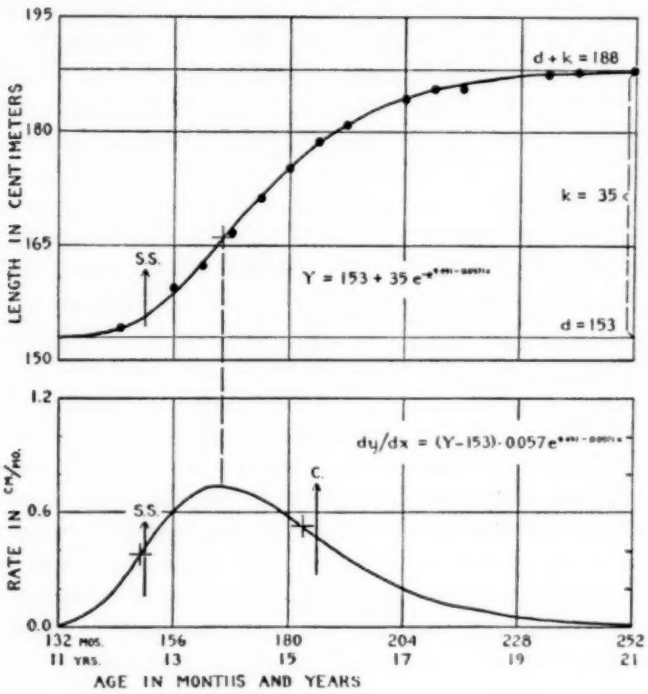


FIG. 2. CALCULATED GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE FOR ADOLESCENT CYCLE OF GROWTH IN LENGTH OF AN INDIVIDUAL BOY, W. S.

Dots are observed length measurements.

Crosses mark points of inflection. *SS* indicates first sign of secondary sex development. *C* indicates fusion of capitellum of humerus.

shown in fig. 4 are by no means exceptional in the close correspondence of their observed length to the pattern of the calculated Gompertz curves. It would seem that the urge for growth in length to proceed according to this pattern during adolescence is so strong that it would be difficult for anything to modify it significantly.

Most of the girls appear to get started on the adolescent growth cycle about 1½ to 2 years younger than the age when most of the boys get started on the cycle. By virtue of this earlier start, the girls soon become, for a time, considerably taller than the boys of corresponding age, only to be outstripped, however, by the boys later on. (See fig. 1.)

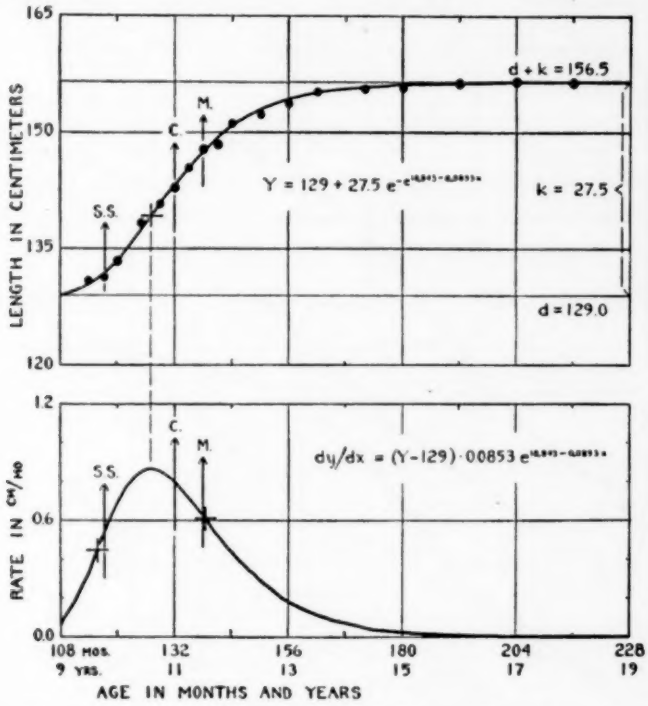


FIG. 3. CALCULATED GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE FOR ADOLESCENT CYCLE OF GROWTH IN LENGTH OF AN INDIVIDUAL GIRL, M. P.

Dots are observed length measurements.

Crosses mark points of inflection. *SS* indicates first sign of secondary sex development. *C* indicates fusion of capitellum of humerus. *M* indicates menarche.

In addition to the differences in timing of the adolescent cycle, we find individual differences and sex differences in the magnitude of the gain in length during the cycle and in the rate at which this gain is accomplished. But in all of these boys and girls the observed pattern of the adolescent cycle lends itself to being fitted satisfactorily by the Gompertz equation, now to be described in detail.

GENERAL DESCRIPTION OF THE GOMPERTZ CURVE

The simplest and most meaningful way of stating the Gompertz equation (though this is not the form that was used by Gompertz himself) is:

$$y = Ke^{-e^{a-bx}} \qquad (K, a, \text{ and } b \text{ being positive constants}). \qquad (1)$$

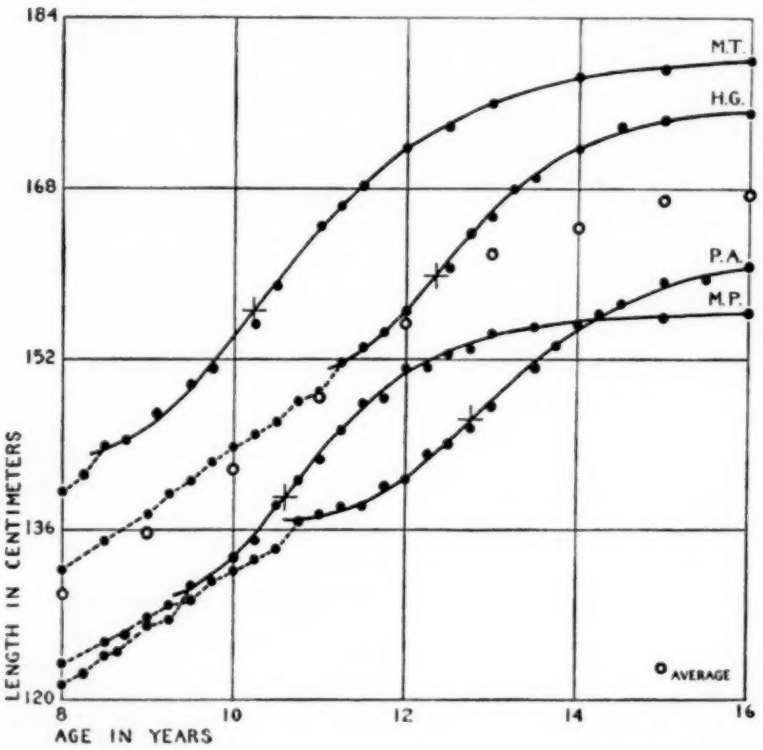


FIG. 4. AVERAGED ANNUAL LENGTH MEASUREMENTS (OPEN RINGS) OF 24 GIRLS FOR PERIOD FROM 8 TO 16 YEARS, COMPARED WITH OBSERVED MEASUREMENTS AND CALCULATED GOMPERTZ CURVES FOR 4 GIRLS OF SAME GROUP OF 24.

Note inadequacy of the averaged annual measurements as a description of individual growth during this age period.

Note also that the 16-year length of these girls could be predicted more accurately at 8 years than at 12 years.

The curve is a skewed S-shaped exponential curve with both a lower and an upper horizontal asymptote, the vertical distance between the

asymptotes being represented by the constant K. With equation (1) the lower asymptote is $(y = 0)$ and the upper asymptote is $(y = K)$. In equal intervals of time, x, the proportion y/K increases to equal powers of itself.

At any point on the Gompertz curve:

$$\frac{y}{K} = e^{-e^{a-bx}} \tag{2}$$

and:

$$\log_e\left(-\log_e\left(\frac{y}{K}\right)\right) = a - bx. \tag{3}$$

The logarithmic equation (3) is a straight line, which can be calculated by the method of least squares if we know, or can estimate, the value of K. This straight line (3) has a negative slope $(-b)$ and a positive y-intercept (a). The x-intercept is $\frac{a}{b}$, the values of $(a - bx)$ being positive before that point and negative after it.

The absolute rate of growth, at any point on the Gompertz curve, is expressed by the first derivative. Differentiating, we have:

$$\frac{dy}{dx} = Ke^{-e^{a-bx}} \cdot be^{a-bx} \tag{4}$$

or, substituting from (1):

$$\frac{dy}{dx} = y \cdot be^{a-bx}. \tag{5}$$

The relative rate of growth decreases exponentially with increase of time:

$$dy/y = be^{a-bx}. \tag{6}$$

To Gompertz (1825), dealing with life tables, this property of the relative rate meant that man's power to avoid death is of such a nature that "in equal small intervals of time he loses equal proportions of his remaining power to resist destruction." Winsor ('32), considering the application of the Gompertz curve to the growth of biological organisms, suggests the paraphrase: "In equal small intervals of time the organism loses equal proportions of its power to grow."

By setting the second derivative of the Gompertz curve equal to zero, we find the abscissa of the point of inflection of the Gompertz curve. This point is also the point at which the first derivative reaches its maximum value.

Differentiating a second time, we have:

$$\frac{d^2y}{dx^2} = Ke^{-e^{a-bx}} \cdot b^2 e^{a-bx}(e^{a-bx} - 1). \tag{7}$$

Setting the factor $(e^{a-bx} - 1)$ equal to zero, we have, for the point of inflection of the Gompertz curve (maximum point of first derivative curve):

$$\begin{cases} e^{a-bx} = 1 & (8) \\ a - bx = 0 & (9) \\ x = \dfrac{a}{b}. & (10) \end{cases}$$

and for the ordinate, from (1) and (8):

$$y = Ke^{-1} \qquad (= \text{approx. } 36.8\% \text{ of } K). \tag{11}$$

and for the maximum rate of growth, from (5) and (8):

$$\frac{dy}{dx} = bKe^{-1}. \tag{12}$$

The curve of the first derivative of the Gompertz curve is similar in general appearance to a logarithmic normal curve. Starting (approximately) from a lower limit of zero, the rate rises steeply, reaching its maximum at the point corresponding to the point of inflection of the *S*-shaped Gompertz curve. It then declines more gradually and finally approaches zero again as a limit as the Gompertz curve approaches its own upper asymptote. The derivative curve has two points of inflection, one before the maximum point and one after the maximum point. They are equally distant in time from the maximum point, as is shown by (16) and (19) below; but the second point of inflection is at a higher vertical level than the first point of inflection, as is shown by (18) and (21) below. The abscissas of the two points of inflection are found by setting the third derivative equal to zero.

Differentiating a third time, we have:

$$\frac{d^3y}{dx^3} = Ke^{-e^{a-bx}} \cdot b^3 e^{a-bx}(e^{2(a-bx)} - 3e^{a-bx} + 1). \tag{13}$$

The factor $(e^{2(a-bx)} - 3e^{a-bx} + 1)$ is a quadratic expression in e^{a-bx}. Setting it equal to zero, we have:

$$\begin{cases} e^{a-bx} = \dfrac{3 \pm \sqrt{5}}{2} = \begin{cases} 2.61803 \\ \text{or} \\ 0.38197 \end{cases} & (14) \\ a - bx = \pm 0.9625. & (15) \end{cases}$$

Solving for the first point of inflection:

from (15): $$x = \frac{a}{b} - \frac{1}{b}(0.9625) \tag{16}$$

from (1) and (14): $$y = Ke^{-2.61803} \ (= \text{approx. } 0.073\,K) \tag{17}$$

from (5) and (14): $$\frac{dy}{dx} = 2.61803\,bKe^{-2.61803} \ (= \text{approx. } 0.191\,bK). \tag{18}$$

Solving for the second point of inflection:

from (15): $$x = \frac{a}{b} + \frac{1}{b}\,(0.9625) \tag{19}$$

from (1) and (14): $$y = Ke^{-0.38197} \ (= \text{approx. } 0.683\,K) \tag{20}$$

from (5) and (14): $$\frac{dy}{dx} = 0.38197\,bKe^{-0.38197} \ (= \text{approx. } 0.261\,bK). \tag{21}$$

APPLICATION OF THE GOMPERTZ CURVE TO THE ADOLESCENT CYCLE OF HUMAN GROWTH

Equation (1) describes an observed pattern of growth only when the observed pattern appears to be an *S*-shaped cycle starting approximately from zero level, as is the case for some forms of animal and plant life.

For the more complex pattern of human growth (fig. 1) we have seen that this is not the case. The *S*-shaped pattern, to which the Gompertz curve is applicable, does not begin at the zero level for actual length of the individual, but appears to start abruptly as a new cycle after a considerable portion of the total growth has already been completed. Therefore, in fitting the Gompertz curve to the observed adolescent growth cycle of a human individual, we cannot use for the actual length of the individual (starting from zero length) the same symbol that we use for the ordinate of the Gompertz curve itself (starting from the lower asymptote of the curve). In order to state the Gompertz equation in terms of the length of the growing individual, we take the symbol Y to denote the actual length of the individual, at any point, and we retain the symbol y for the ordinate of the Gompertz curve itself, at any point. It then becomes necessary to add to the equation another

positive constant, d, to represent the level of the lower asymptote of the Gompertz curve. This gives us the equation that was used for calculating the curves reported in the present paper:

$$Y = d + y = d + Ke^{-e^{a-bx}}. \tag{22}$$

When equation (22) is applied to the observed adolescent growth cycle of individual boys and girls, the age of the individual, at any point, is represented by x, with $(x = 0)$ at birth. The actual length of the individual, at any point, is represented by Y. The ordinate, y, of the Gompertz curve is equal to $Y - d$, and represents the length that has been gained, at any point, by the individual after starting on his adolescent cycle of growth. The lower asymptote of the Gompertz curve, representing the length that had already been attained by the boy or girl before the start of the adolescent growth cycle, is $(Y = d)$. The upper asymptote, representing the adult length of the individual, is $(Y = d + K)$. The constant K represents the individual's total gain in length during the adolescent growth cycle. The constant b represents the rate at which the proportion y/K is increasing to equal powers of itself. This constant may be thought of as the individual's constant inherent rate of maturation through the S-shaped adolescent growth cycle. The constant a is merely the intercept at $(x = 0)$ of the logarithmic straight line (3). The proportion a/b, which is the abscissa of the point of inflection of the Gompertz curve, represents the age of the boy or girl at the point of inflection, which is also the point of maximum rate of growth of the individual. The product bKe^{-1} represents the maximum rate of growth attained.

The derivatives of the Gompertz curve remain the same, whether we state the original equation in the form of (1) or in the form of (22). We may use the symbol dy/dx or the symbol dY/dx interchangeably, since the additional constant, d, in equation (22) does not change the value of the derivative. However, the symbol y must be retained in those derivative equations which contain it, namely (5) and (6). And it must be remembered that, with equation (22), the symbol y denotes not the actual length of the growing individual but the length he has gained, at any point, after starting on his adolescent growth cycle.

A Gompertz curve and first derivative curve fitted to the observed adolescent growth cycle of an individual boy and an individual girl, respectively, can be seen in figs. 2 and 3.

The actual calculation of the curves reported in the present paper

was done by means of the *Courtis table of isochrons.* This table is very helpful for fitting the Gompertz curve to observed data, because it converts the observed values of the percentage $100\,y/K$ directly to linear $\log_e(-\log_e)$ units called *isochrons,* thus doing away with the necessity of looking up natural logs twice over for every observed point used in the calculation of the curve.

The relation of the Courtis *isochron* to the Gompertz curve as described by equations (1), (2), and (3) can be explained as follows:

The Courtis *isochron* is 1/10 of the Courtis *T-unit.* The *T-unit* is defined, in effect, by Courtis ('32) as the time required for the proportion y/K at the point of inflection of the Gompertz curve to increase to its own power of itself. The number of *T-units* corresponding to the proportion y/K, at any point on the Gompertz curve, is represented by the symbol T, with $(T=0)$ at the point of inflection.

At the point of inflection of the Gompertz curve:

by definition:	$T=0$
from (11):	$\dfrac{y}{K}=e^{-1}$
	$\log_e\left(-\log_e\left(\dfrac{y}{K}\right)\right)=0$
from (3) or (9):	$a-bx=0$
	$x=\dfrac{a}{b}.$

At the point where the proportion y/K at the point of inflection has increased to its own power of itself:

by definition:	$T=1$
by increasing to its own power of itself:	$\dfrac{y}{K}=(e^{-1})^{e^{-1}}=e^{-e^{-1}}$
	$\log_e\left(-\log_e\left(\dfrac{y}{K}\right)\right)=-1$
from (3):	$a-bx=-1$
	$x=\dfrac{a}{b}+\dfrac{1}{b}.$

Thus we see that 1 *T-unit* is $(a/b+1/b-a/b)$ x-units $=1/b$ x-units.

In order to find the number of *T-units* corresponding to any number of x-units, we divide the number of x-units by $1/b$. Since $T = 0$ when $x = a/b$, the relation between T and x is:

$$T = \frac{x - \frac{a}{b}}{\frac{1}{b}} = -a + bx. \tag{23}$$

It is obvious that equation (23) is a straight line, and that this straight line is the mirror image, about $(x = a/b)$, of the logarithmic straight line (3).

Since the Gompretz curve is asymptotic, it follows that the proportion y/K can never actually be zero, except at minus infinity, and can never actually be 1, except at plus infinity. For practical purposes, an arbitrary "zero time" is taken by Courtis ('32) at the point where $T = -3$, at which point he states that the percentage $100\,y/K$ is 0.000000189%. (At this point, from (23): $x = a/b - 3/b$.) Likewise, for the approximate time of "maturity" or completion of the growth cycle, Courtis ('32) takes the point where $T = 7$, at which point he states that the percentage $100\,y/K$ is 99.90917%. (At this point, from (23): $x = a/b + 7/b$.) The total duration of the *S*-shaped growth cycle is covered, for practical purposes, by 10 *T-units*.

In order to have a unit of convenient magnitude for calculations, Courtis ('32) takes the *isochron* as 1/10 of the *T-unit*, *i.e.*, as 1/10 of the time required for the proportion y/K at the point of inflection of the Gompertz curve to increase to its own power of itself, and as 1/100 of the approximate total duration of the *S*-shaped growth cycle represented by the Gompertz curve. The number of *isochrons* corresponding to the percentage $100\,y/K$, at any point on the Gompertz curve, is represented by the symbol I. Courtis ('32) takes the zero value of I at "zero time"—*i.e.*, $I = 0$ when $T = -3$.

Then, by definition:

$$I = 10(T + 3) \tag{24}$$

and, substituting from (23):

$$I = 10(-a + bx + 3) = 30 - 10a + 10bx. \tag{25}$$

Courtis ('32) writes this *isochronic* straight line in the form:

$$I = i + Rx \tag{26}$$

where, evidently: $i = 30 - 10a$ (27)

and: $R = 10b.$ (28)

All meaningful values of I are positive. But when, as is the case with the adolescent growth curve, the "zero time" for the start of the S-shaped growth cycle is a later time than $(x = 0)$, the projected intercept, i, at $(x = 0)$ will be negative.

Some equivalents that may be helpful are:

from (25): $a - bx = (30 - I)/10$ (29)

from (3) and (29): $\log_e\left(-\log_e\left(\frac{y}{K}\right)\right) = (30 - I)/10$ (30)

from (27): $a = (30 - i)/10$ (31)

from (28): $b = R/10$ (32)

from (31) and (32): $\frac{a}{b} = \frac{30 - i}{R}.$ (33)

METHOD OF FITTING THE CURVE

As the first step in fitting the Gompertz curve to the observed growth of each of the 48 adolescents, we plotted the longitudinal series of length measurements of the boy or girl on a graph similar to fig. 1, with the length in cm represented by Y, and the age in months represented by x, with $(x = 0)$ at birth. Suitable levels for the upper and lower asymptotes of the S-shaped adolescent growth curve were then located by inspection from the pattern of the plotted points. The upper asymptote $(Y = d + K)$ was not difficult, because these boys and girls had stopped growing in length, according to our measurements, before the curves were fitted. We merely used the apparent "ceiling" to the nearest half cm as the approximate upper asymptote of the curve. The lower asymptote $(Y = d)$ was not always so easily located. In some cases, as for the boy in fig. 1, the take-off of the S-shaped growth cycle seemed very obvious, and there was no difficulty in estimating a suitable level for the lower asymptote. In other cases, as for the girl in fig. 1, the beginning of the S-shaped cycle was not so well defined. In such a case

it was sometimes necessary to try several different estimates for the level of the lower asymptote and select the one which gave the best fit.

Having decided on the levels for the asymptotes, we could determine, for any point, the Gompertz curve ordinate $(y = Y - d)$, and we had our value for the constant K, which is the vertical distance between the asymptotes. We then selected 10 or 12 of the plotted observed points along the course of the S-shaped growth cycle, to be used for calculating the curve. We did not use, for the calculation, points lying close to either of the asymptotes, because a small error in an observed point near the asymptote involves a disproportionately large error in the corresponding log, and can cause undue distortion of the calculated straight line. Also, if one observed point appeared to deviate markedly from the general trend of the points, we would omit that particular point from the calculation.

For each of the selected observed points we calculated the percentage $100y/K$ and then obtained from the Courtis table the corresponding *isochron* value, I. The series of values of I, when plotted against corresponding values of x, lie approximately in a straight line, if suitable levels for the asymptotes of the curve have been chosen. If these values of I do not appear to make a straight line, it is an indication that a different asymptote should be tried. The *isochronic* straight line (26), $I = i + Rx$, was fitted through the series of values of I by means of the method of least squares. The calculated constants, i and R, were then converted by (31) and (32) to equivalent constants, a and b, for stating the Gompertz curve in its exponential form.

In order to draw the S-shaped exponential curve, we calculated the *isochron* value, I, for as many points as seemed desirable for drawing a good curve, and then converted each calculated I to the corresponding percentage $100y/K$ by means of the Courtis table. With this percentage known, it was easy to obtain first y, and then Y $(= y + d)$, for each of the calculated points. The curve was then drawn through the calculated (x, Y) points with the help of a curved ruler. Points for drawing the first derivative curve were obtained by substituting in equation (5) our calculated values of y, b, and $(a - bx)$. The abscissa and ordinate of the point of inflection of the Gompertz curve were determined by substituting in (10) and (11), respectively. The two points of inflection of the first derivative curve were located by substituting in (16) and (18) and in (19) and (21). The maximum point of the first derivative curve was located by substituting in (10) and (12).

For those who may be interested, a complete sample calculation of a Gompertz curve and its first derivative cure is appended at the end of this paper together with a calculation of points.

DISCUSSION OF FINDINGS

The various constants, asymptotes, and points of inflection of the 48 calculated Gompertz curves and first derivative curves give us a useful means of studying the typical pattern of growth in length during the adolescent growth cycle and the relation of certain physiological events to the pattern of the growth cycle. (See figs. 2 and 3.) They also give us a means of comparing or ranking individual boys or girls with respect to certain aspects of their pattern of growth, and a means of investigating sex differences in growth during the adolescent cycle.

Mean values and standard deviations for the constants, asymptotes, and points of inflection are listed in table 1. For all of these constants and landmarks of the fitted curves we find a considerable range of individual variation among the 24 boys and among the 24 girls of our group, and also some overlapping of the two sexes. However, as can be seen in table 3, we find strikingly significant sex differences, both with respect to magnitude of the constants and asymptotes and with respect to timing of the points of inflection of the curves.

Sex differences with respect to magnitude of the constants and asymptotes.

The lower asymptote ($Y = d$), which corresponds to the length already attained by the boy or girl at the time of starting on the *S*-shaped adolescent growth cycle, shows a significant 9 cm difference between the girls' mean of 141 cm and the boys' mean of 150 cm. This tendency for the girls to be shorter at start of the adolescent cycle is not surprising, because they tend also to be significantly younger than the boys, by about 1½ to 2 years, at the time of starting on the new cycle. (See fig. 1.)

The upper asymptote ($Y = d + K$), which corresponds to the adult length of the individual, shows a still greater difference between the girls' mean of 169 cm and the boys' mean of 183½ cm.

The constant K, representing the total gain in length during the adolescent growth cycle, shows a significant 5.3 cm difference between the girls' mean gain of 28.1 cm and the boys' mean gain of 33.4 cm. The typical larger gain of the boy is illustrated by fig. 1 and by a

TABLE 1

Constants, asymptotes, and points of inflection of the Gompertz curve for adolescent cycle of growth in length and its first derivative curve—24 girls and 24 boys

	MEAN FOR 24 GIRLS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	MEAN FOR 24 BOYS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Lower asymptote ($Y = d$) in cm (Length at start of the adolescent growth cycle)	140.8125	5.5205	± 1.15110	149.9375	4.44952	± 0.927789
Upper asymptote ($Y = d+K$) in cm (Adult length)	168.908	5.71354	± 1.19136	183.350	5.13907	± 1.07157
Constant K in cm (Length gained during the adolescent growth cycle)	28.0875	3.91938	± 0.817247	33.4125	3.43631	± 0.716520
Proportion of adult length contributed by K	16.6167%	2.23277%	± 0.465565%	18.2167%	1.70568%	± 0.355659%
Rate-constant b(T-units/mo.)	0.0736208	0.00781303	± 0.00162918	0.0654625	0.00520711	± 0.00108576
Growth pattern index ($100\ b/K$)	0.268792	0.0549772	± 0.0114635	0.198875	0.0314275	± 0.00655309
Constant a (Intercept of logarithmic straight line)	10.0855	1.35471	± 0.282478	10.5492	0.960281	± 0.200267
Age in mos. at point of inflection of Gomperts curve ($x = a/b$) (Rate is max.)	136.956	11.3295	± 2.36238	161.295	10.4238	± 2.17353
Age in mos. at 1st point of inflection of 1st derivative ($x = a/b - 1/b$ (0.9625))	123.734	11.5071	± 2.39940	146.5004	10.2837	± 2.14431
Age in mos. at 2nd point of inflection of 1st derivative ($x = a/b + 1/b$ (0.9625))	150.1725	11.3249	± 2.36141	176.0964	10.6785	± 2.22664
Interval in mos. between max. point and 1st or 2nd point of inflection of 1st derivative ($= \pm 1/b$ (0.9625))	± 13.2208	1.38062	± 0.287879	± 14.7950	1.16886	± 0.243724
Maximum rate of growth in cm/mo. ($dy/dx = bKe^{-1}$)	0.755833	0.098087	± 0.0204525	0.801375	0.0711388	± 0.0148335

TABLE 2

TABLE 2

Timing of some physiological events in relation to the Gompertz curve for the adolescent cycle of growth in length—24 girls and 24 boys

	MEAN FOR 24 GIRLS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN	MEAN FOR 24 BOYS	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Age in mos. for 1st observed point on the Gompertz curve	119.750	11.8717	± 2.47542	140.1250	9.90023	± 2.07060
Age in mos. for 1st obs. of secondary sex development	121.625	12.4593	± 2.59796	142.1667	10.3463	± 2.15735
No. of mos. by which 1st obs. of secondary sex development precedes (—) or follows (+) 1st observed point on curve	+ 2.00000	7.33144	± 1.52871	+ 1.87500	10.0553	± 2.09667
No. of mos. by which 1st obs. of secondary sex development precedes (—) or follows (+) 1st point of inflection of the 1st derivative curve	— 2.10917	7.91943	± 1.65131	— 4.33375	10.0004	± 2.08523
No. of mos. by which 1st obs. of secondary sex development precedes point of inflection of the Gompertz curve	— 15.3333	7.82532	± 1.63169	— 19.5875	9.34943	± 1.94949
Age in mos. when X-ray shows fusion of the capitellum of the humerus ($N = 18\,♀, 20\,♂$)	142.389	9.49183	± 2.30210	180.9000	10.0891	± 2.31460
No. of mos. by which fusion of capitellum follows after point of inflection of the Gompertz curve ($N = 18\,♀, 20\,♂$)	+ 7.27778	4.21930	± 1.02333	+ 17.6400	5.35079	± 1.22756
No. of mos. by which fusion of capitellum precedes (—) or follows (+) 2nd point of inflection of the 1st derivative curve ($N = 18\,♀, 20\,♂$)	— 6.23556	4.29596	± 1.04192	+ 2.92950	5.38295	± 1.23493
Age in mos. at the menarche	151.625	12.3003	± 2.56479			
No. of mos. by which menarche follows after point of inflection of the Gompertz curve	+ 14.6625	4.41209	± 0.919985			
No. of mos. by which menarche precedes (—) or follows (+) 2nd point of inflection of the 1st derivative curve	+ 1.44167	4.44399	± 0.926636			

TABLE 3

Significant sex differences associated with the Gompertz curve for adolescent cycle of growth in length and its first derivative—48 adolescents

	MEANS FOR 24 GIRLS	MEANS FOR 24 BOYS	DIFFERENCE BETWEEN MEANS	SIGNIFICANCE t	P
Lower asymptote ($Y = d$) in cm (Length at start of cycle)	140.8125	149.9375	9.1250	6.172	< 0.001
Upper asymptote ($Y = d + K$) in cm (Adult length)	168.908	183.350	14.442	9.013	< 0.001
Constant K in cm (Length gained during adolescent cycle)	28.0875	33.4125	5.3250	4.899	< 0.001
Rate-constant b in T-units per month	0.0736208	0.0654625	0.0081583	4.167	< 0.001
Growth pattern index $100\ b/K$	0.268792	0.198875	0.069917	5.295	< 0.001
Age in mos. at point of inflection of Gompertz curve ($x = a/b$)	136.956	161.295	24.339	7.581	< 0.001
Age in mos. at 1st point of inflection of 1st derivative curve	123.734	146.500	22.766	7.075	< 0.001
Age in mos. at 2nd point of inflection of 1st derivative curve	150.1725	176.0904	25.9179	7.985	< 0.001
Interval in mos. between point of maximum rate and 1st or 2nd point of inflection of derivative ($= \pm 1/b$ (0.9625))	$\pm$13.2208	$\pm$14.7950	1.5742	4.173	< 0.001
Age in mos. for 1st obs. point on Gompertz curve	119.750	140.1250	20.375	6.313	< 0.001
Age in mos. for 1st obs. of secondary sex devel.	121.625	142.167	20.542	6.083	< 0.001
Age in mos. when X-ray shows fusion of capitellum of humerus	142.389 ($N = 18$)	180.900 ($N = 20$)	38.511	11.759	< 0.001
Interval in mos. from point of inflection of Gompertz curve to fusion capitellum of humerus	7.2778 ($N = 18$)	17.6400 ($N = 20$)	10.3622	6.534	< 0.001

comparison of the girl's curve shown in fig. 3 and the boy's curve shown in fig. 2. Not only does the actual magnitude of K tend to be greater for the boys than for the girls, but there is also a significant tendency for the proportion of total adult length that is contributed by K to be somewhat greater in the boys. The mean value of this proportion is 16.6% of adult length for our girls, and 18.2% for our boys. By t-test for significance of difference $t = 2.731$; P is approximately 0.008.

The rate-constant b also shows a significant sex difference. This constant represents the rate (Courtis *T-units* per month) at which the proportion y/K is increasing to equal powers of itself. It is the individual's constant inherent rate of progress toward completion of the S-shaped growth cycle. The total range of individual variation for this constant looks small. But within this range there is a very significant difference in favor of a more rapid inherent rate of progress for the girls than for the boys.

Thus we find that the typical male pattern of growth during the adolescent cycle is characterized by a large total gain in length and a comparatively slow rate of progress in completing the cycle, while the typical female pattern is characterized by a smaller total gain in length and a more rapid rate of progress in completing the cycle.

A convenient index for describing the growth pattern of an individual, and for comparing or ranking individuals with respect to growth pattern, is the proportion b/K, which, like b and K, shows a significant sex difference, the smaller values of this index being typical for the boys and the greater values typical for the girls. In the form $100b/K$ the mean value of the growth pattern index is 0.269 for the girls and 0.199 for the boys. Only one boy has an index greater than the mean index for the girls; and only one girl has an index smaller than the mean for the boys.

There appears to be some relation, at least for the boys of our group, between the growth pattern index $100b/K$ and the general body build of the individual, particularly with reference to androgyny. A study of the nude photographs of these boys at 18 to 21 years reveals a preponderance of typically andric appearing boys among those having the smaller (more typically male) values of the index $100b/K$ and a preponderance of less andric appearing boys among those having the greater (less typically male) values of the index $100b/K$. Fig. 6 is an illustration of this. The two boys whose photographs are shown were selected because they impresed us as being the most andric (A) and the least

andric (B) of the 24 boys of the group. Our evaluation of the androgyny status was based mainly on the criteria of Bayley and Bayer, as quoted by Shuttleworth ('49). In the photographs of (A) note the general leanness of body surface, with muscles and bony prominences clearly

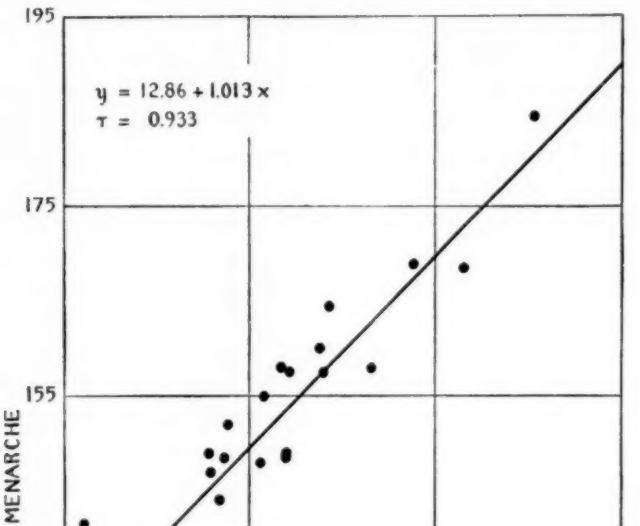


FIG. 5. ILLUSTRATION OF CLOSE CORRELATION OF AGE OF MENARCHE IN 24 GIRLS WITH AGE AT POINT OF MAXIMUM RATE OF GROWTH AS REPRESENTED BY POINT OF INFLECTION OF CALCULATED GOMPERTZ CURVE FOR GROWTH IN LENGTH OF THE SAME 24 GIRLS.

outlined beneath the skin; wide, muscular shoulder girdle; narrow hips; waistline inconspicuous and relatively low on the trunk; tight, muscular buttocks with deep concavities; lower extremities relatively long in proportion to total body height; thin, straight-sided thighs with an open

space between them; bulging calf muscles on inner side of leg. In the photographs of (B) note the general softness of body contours with muscles and bony prominences obscured by subcutaneous fat; hips wider in proportion to the shoulders; waistline more noticeable and relatively higher on the trunk; soft, cushion-like buttocks with very little concavity; lower extremities relatively short in proportion to total height; wide, funnel-shaped thighs with no space between them; less bulging of calf muscles on inner side of leg and greater curvature on outer side of leg. When the 24 boys of our group are ranked from the smallest to the greatest value of the growth pattern index $100b/K$, we find that (A) ranks 4th in smallness of this index (very typically male) and that (B) ranks 24th (least typically male), being also the only boy with an index greater than the mean index for girls of our group.

A study of the photographs of the girls of our group did not reveal any such striking example of correspondence between the growth pattern index and androgyny status. The relation, if any, would seem to be less clear-cut for the girls than for the boys.

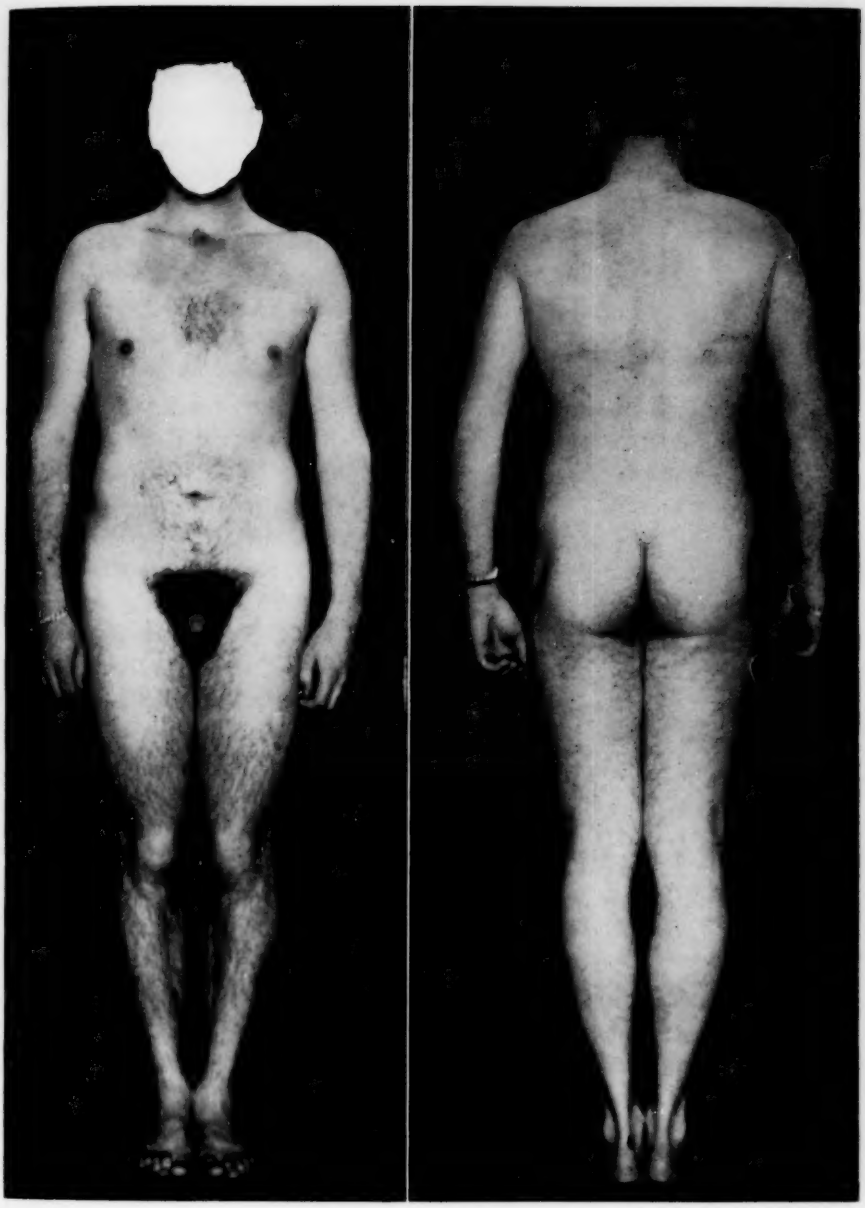
Sex differences with respect to timing of the points of inflection of the curves.

The point of inflection of the *S*-shaped growth curves has been variously regarded as important or unimportant by different research workers in the field of growth. Extremes in attitude toward this point of maximum rate of growth are exemplified on the one hand by Weymouth, McMillin, and Rich ('31) and on the other hand by Brody ('27). Weymouth, McMillin, and Rich, who applied the Gompertz curve sucessfully to the growth in length of razor clams, as well as to Donaldson's data for growth of the rat in weight, believe that the point of inflection (point of maximum rate of growth) is of the nature of an artifact, with no biological significance, and that the curve of the relative rate—which decreases exponentially in a continuous smooth progression with no point of inflection—is much more significant than either the Gompertz curve itself or the curve of the absolute rate as represented by the first derivative. Brody, on the other hand, regards the point of inflection of the growth curves of both man and animals as a significant point for comparison of individuals or of species, and believes that this point is significantly related to puberty in both man and animals. Moreover, the findings of Shuttleworth ('39), with data from the Harvard Growth Study, and of Tanner ('51), with data from the

A A

FIG. 6. BOY (A) WITH TYPICALLY MALE GROWTH PATTERN INDEX b/K AND BOY (B) WITH LEAST TYPICALLY MALE INDEX b/K. COMPARE ANDROGYNY STATUS OF THE 2 BOYS.

Anterior views are at 18–19 years, posterior views at 21 years.



B B

Harpenden Growth Study, as well as the work of Simmons and Greulich ('43), with data from the Brush Foundation Series, and the earlier work of Boas ('32), with children from various New York schools, all point to a significant relationship between timing of the year of maximum increment in stature (which is at least closely related to timing of the point of inflection of the growth curve) and various other aspects of the individual's growth and development, including sexual maturation.

At the Child Research Council we find the point of inflection of the growth curve a meaningful and useful landmark, both for ranking boys or girls from the standpoint of early or late maturing and for investigating relations with other aspects of growth. Our group of 48 adolescents shows a significant sex difference of about two years between the girls' mean age at point of inflection of the Gompertz curve for growth in length and the boys' mean age at this point, the girls' mean age being not quite 137 months (11 yrs. 5 mos.) and the boys' mean being a little more than 161 months (13 yrs. 5 mos.). The mean ages for our boys and girls at this point of maximum absolute rate of growth are a year younger than the mean ages at "maximum growth" reported by Shuttleworth ('39) for 747 girls and 711 boys from the Harvard Growth Study. Shuttleworth, however, is not actually dealing with maximum rate of growth, as represented by the derivative at one particular point, but with the maximum increment achieved during an entire year. Since he takes his "age of maximum growth" at the end of the year of greatest gain, we should expect the point of inflection to be somewhere about the middle of that year and several months earlier than *MG*-age of Shuttleworth. Even allowing for this difference, however, the mean ages for our small group, at the point of maximum rate of growth, would appear to be somewhat younger than Shuttleworth's findings would lead us to expect.

We find significant sex differences, also, for age at each of the two points of inflection of the first derivative curve. As can be seen in table 3, the sex difference for the first point of inflection of the derivative curve is somewhat less than the difference for the point of maximum rate, and the difference for the second point of inflection is greater than the difference for the maximum point. This is a result of the sex difference, already mentioned, in the rate-constant *b*, which, as time goes on, makes for increasing advancement of the girl and increasing retardation of the boy, with respect to the proportion of the total adolescent growth cycle that has been completed at a given time.

We find still another significant sex difference in the time interval between the point of maximum rate and either of the two points of inflection of the derivative curve. This, too, is a result of the sex difference in the constant b, since the time interval is equal to $\pm 1/b$ (0.9625), as shown under the general description of the Gompertz curve and its derivative curve. The typical difference in shape of the derivative curves of the boy and the girl, which results from sex difference in the time interval between maximum point and inflection points, is strikingly illustrated by the wide derivative curve of the boy shown in fig. 2 and the much narrower derivative curve of the girl shown in fig. 3.

The maximum rate of growth itself, in cm per month, as represented by the derivative at the point of inflection of the Gompertz curve, does not show a significant sex difference for the 48 boys and girls of our group, though the boys' mean rate at the maximum point is slightly more rapid than that of the girls. This is due in part to the fact that the maximum rate depends on the product of the constants b and K ($dy/dx = bKe^{-1}$ at maximum point). This product neutralizes the sex differences for the individual constants, since K tends to be significantly greater for the boys while b tends to be significantly smaller for the boys.

The failure of our boys and girls to show a significant sex difference in maximum rate of growth attained might seem surprising in view of the findings of Shuttleworth ('39) and of Tanner ('51), in favor of a greater "peak velocity" of growth in height for boys than for girls. However, as has been pointed out, both Shuttleworth and Tanner were dealing with maximum increment for an entire year—not with velocity of growth, which is in a state of continual change from moment to moment throughout the year. Our boys do show a greater gain in length than our girls, for the adolescent cycle as a whole, as is shown by the sex difference in the value of the constant K. But the continually changing rate at which they are achieving that gain may or may not reach a higher point, at any time, than the maximum point that may be reached by a girl's rate. This, too, is illustrated by the boy's derivative curve in fig. 2 and the girl's derivative curve in fig. 3. This particular girl made a much smaller gain in length during her adolescent growth cycle than the gain made by the boy, but she attained, for a brief time, a more rapid rate of gain than was ever attained by the boy. Offsetting this, the boy, as is typical, maintained a rate of gain somewhere near his maximum rate over a considerably longer period of time than was possible for the girl, due to the girl's greater inherent urge toward rapid completion of the growth cycle, as represented by the constant b.

Timing of certain physiological events in the 48 adolescent boys and girls.

Means and standard deviations for timing of certain physiological events in these boys and girls, and for the relation of these events to the landmarks of the calculated growth curves, are listed in table 2. Here again, as would be expected, we find some significant sex differences, which are listed in table 3.

The age at which any boy or girl reached a length equivalent to the lower asymptote of the Gompertz curve and started on the new *S*-shaped growth cycle cannot be known exactly, because these boys and girls were measured not oftener than once in three months. A crude approximation, usually somewhat too high, is the age when the plotted observed length of the individual first appears to lie approximately on the *S*-shaped curve. (See the various locations of this first observed point on the curves shown in figs. 1 and 4.) Mean age for the first observed point on the adolescent curve is approximately 120 months (10 years) for the girls and 140 months (11 yrs. 8 mos.) for the boys, with a significant 20 months difference between the means.

Usually within a few months before or after the first observed point on the adolescent curve for growth in length we note the first recorded observation, by the pediatric examiner, of evidence of beginning secondary sex development in the boy or girl. Our records are by no means so accurate or complete, with respect to this finding, as we might wish, particularly for the older boys of our group. Individual examiners have varied both in their zeal for observing and recording the very earliest signs of secondary sex development and in their criteria for stating whether or not such development has started. At no time have the boys of the Child Research Council Series had actual measurements of size of the penis and testes, such as are reported by Tanner ('51) for the boys of the Harpenden Growth Study. Nor do we have "close-up" photographs of the genital region of the boys, such as are shown in the pictorial atlas of Shuttleworth ('49). The first secondary sex sign to be reported in our records has usually been, for the boys, the appearance of a few hairs at the base of the penis, and for the girls, the beginning of breast development. The timing of this first recorded observation is indicated by the letters *SS* on the growth curves shown in figs. 1, 2 and 3. Mean age at the *SS* point is between 121 and 122 months (10 yrs. 1 to 2 mos.) for the girls and approximately 142 months (11 yrs. 10 mos.) for the boys of our group. The interval, plus or minus, between the first observed point on the adolescent growth curve and the first recorded

observation of secondary sex development shows a wide range of individual variation, especially for the boys; but the mean interval, for both sexes, is approximately two months after the first observed point on the growth curve. Nine of the 24 boys and 9 of the 24 girls had the first observation of secondary sex development before the first observed length point on the growth curve, while 15 had the first observation of secondary sex development later than, or synchronous with, the first observed length point on the growth curve.

In many cases we find the *SS* point very close to the first point of inflection of the derivative curve, as is illustrated by figs. 2 and 3. It may be either before or after the first point of inflection, the mean time for the *SS* point being about two months before the first point of inflection for the girls and about 4 months before the first point of inflection for the boys.

In all 48 boys and girls the *SS* point is several months before the point of maximum rate of growth in length, as represented by the point of inflection of the Gompertz curve. The mean time for the *SS* point is about 15 months before the point of maximum rate for the girls and about 19½ months before the point of maximum rate for the boys.

Another physiological event which is of interest in connection with the pattern of growth in length during the adolescent cycle is the fusion of the capitellum of the humerus. This is the first long-bone epiphysis to close, and in the absence of data for the complete skeletal age (which we do not have for the older boys and girls of the Child Research Council Series) it serves as a useful landmark of skeletal maturation. We know the time of fusion of the capitellum for 20 boys and 18 girls of our group of 48 adolescents, based on X-ray films taken every 6 months. We find a very striking sex difference, with no overlapping of the two sexes. Mean age of capitellum fusion is a little more than 142 months (11 yrs. 10 mos.) for the 18 girls and about 181 months (15 yrs. 1 mo.) for the 20 boys, with a significant difference of more than three years between the means. There is also an interesting sex difference in timing of fusion of the capitellum with relation to the growth curve. For both boys and girls we find the fusion occurring at some time after the point of maximum rate of growth, but the interval is significantly longer for the boys than for the girls. The girls' mean interval is about 7 months after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, while the mean interval for the boys is about 17½ months after the point of maximum rate of growth. It is

interesting to note that the rate of growth in length has slowed down considerably, especially for the boys, before any long-bone epiphysis is closed, rather than being slowed as a result of closure of the epiphyses. In many of our boys we find that the timing of capitellum fusion is close to the second point of inflection of the derivative curve, as is illustrated by fig. 2, the mean interval for the 20 boys being not quite three months after the second point of inflection. In 14 boys the fusion follows after the second point of inflection, and in 6 boys it precedes this point. The girls, on the other hand, show fusion of the capitellum before the second point of inflection in all but two cases; and their mean interval for fusion is 6 months before the second point of inflection. The typical sex difference in timing of capitellum fusion with relation to the growth cycle is illustrated by figs. 2 and 3, where fusion is indicated by the letter *C*. The relation of fusion of the capitellum to the adolescent cycle of growth in length will be discussed further under correlations, in a subsequent section of this paper.

The timing of menarche in the girls of this group is, without exception, a number of months after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve. This is in general agreement with findings reported in the literature, for example by Simmons and Greulich ('43), for timing of menarche in relation to the year of maximum increment of standing height. The mean age of menarche for our 24 girls is 151.6 months (not quite 12 yrs. 8 mos.). The mean interval for menarche after the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, is between 14 and 15 months. The girls of our group show a rather close correspondence between timing of menarche and the second point of inflection of the derivative curve. Twenty of the 24 girls (83⅓%) have menarche within 6 months before or after the second point of inflection. Mean interval for the 24 girls is 1.4 months after the second point of inflection. The timing of menarche for the girl whose growth curve is shown in fig. 3 is indicated by the letter *M*. It will be noted that, as is typical, her rate of growth has slowed down very considerably from the maximum rate before the menarche occurs. The relation between menarche and the adolescent growth cycle will be discussed further under correlations.

Correlations.

Some correlation coefficients that are of interest in connection with the calculated Gompertz curves are listed in tables 4 and 5.

A. Correlations involving the constants and asymptotes of the curves (table 4): As would be expected, we find, for each sex, a significant positive correlation (0.756 for the 24 girls and 0.736 for the 24 boys) between adult length, as represented by the upper asymptote, $(d+K)$,

TABLE 4

Correlation coefficients involving the constants and asymptotes

CORRELATION	GIRLS r	GIRLS 95% Limits of confidence (z-transformation)	BOYS r	BOYS 95% Limits of confidence (z-transformation)
$d(d+K)$	0.756	0.888 0.507	0.736	0.879 0.473
dK	—0.306	Not sig.	—0.193	Not sig.
$L_8(d+K)$	0.876	0.945 0.731	0.758	0.889 0.511
$L_{12}(d+K)$	0.736	0.879 0.473	———	———
$L_{14}(d+K)$	———	———	0.447	0.720 0.053
$K(d+K)$	0.391	Not sig.	0.542	0.776 0.177
$b(d+K)$	—0.133	Not sig.	—0.435	—0.713 —0.038
bK	—0.447	—0.720 —0.053	—0.553	—0.782 —0.193
$b/K\ BB$	0.157	Not sig.	0.500	0.752 0.121

Meaning of symbols used:

r = correlation coefficient.
d = length at start of adolescent growth cycle (lower asymptote of curve).
K = length gained during adolescent growth cycle.
L = length at specified ages, 8 years, 12 years, and 14 years.
b = rate-constant.
b/K = growth pattern index.
BB = body build index at 18 to 19 years.
Not. sig. = not significantly different from zero, by t-test for a sample of 24.

and length at the start of the adolescent growth cycle, as represented by the lower asymptote, d. This correlation is less striking than might perhaps be expected, due in part to the fact that some of the individuals who are taller at the start of the adolescent growth cycle are taller by virtue of starting the cycle at a later age and are therefore affected by

the tendency, which we also find (see table 5) for the later maturing boys and girls to make a smaller gain in length during the adolescent cycle than the earlier maturing boys and girls. Even apart from differences in age at time of starting on the new cycle, we find that the individuals who have attained the greatest length before the start of the cycle are not necessarily the ones who achieve the greatest gain during the adolescent cycle itself. For neither the boys nor the girls of our group did we obtain a significant correlation between the adolescent gain, K, and length at time of starting on the adolescent cycle, as represented by the lower asymptote, d. Moreover, the small correlations which we did obtain are in a negative rather than a positive relation.

Our correlation between adult length $(d + K)$ and length at start of the adolescent cycle does not, of course, imply any specific age. For purposes of comparison we also calculated, for each sex, the correlation between adult length $(d + K)$ and the observed length of the same individuals at two specific ages—8 years and 12 years for the girls and 8 years and 14 years for the boys. The correlations with length at 8 years are somewhat better than our correlations with length at start of the adolescent cycle, as represented by d. In contrast to this, the correlation with length at 12 years for the girls and the correlation with length at 14 years for the boys are less good than either the correlation with length at 8 years or the correlation with length at start of the cycle, as represented by d. Fig. 4 is a good illustration of the temporary distortion of relative position of individuals in a group, which may be caused by differences in timing and intensity of growth during the adolescent cycle, and which would lead us to expect a better correlation between adult length and length of these girls at 8 years than we would expect between adult length and length of the same girls at 12 years. Our better correlations with length at 8 years than with length at 12 years and 14 years are in general agreement with reports in the literature on correlations between adult standing height and height at various specifc ages, for example by Shuttleworth ('39), with several hundred boys and girls from the Harvard Growth Study, and by Tuddenham and Snyder ('54), with 70 girls and 66 boys from the California Guidance Study.

For the relation between adult length $(d + K)$ and gain during the adolescent cycle, as represented by K, we find a weak but significant positive correlation (0.542) for the 24 boys, but only a suggestive positive correlation (0.391) for the girls. The better correlation for

TABLE 5

Correlation coefficients involving timing of point of maximum rate of growth

CORRELATION	GIRLS r	GIRLS 95% Limits of confidence (z-transformation)	BOYS r	BOYS 95% Limits of confidence (z-transformation)
a/b Max	—0.746	—0.884 —0.490	—0.603	—0.809 —0.264
a/b K	—0.725	—0.873 —0.455	—0.410	—0.705 —0.008
a/b b	0.031	Not sig.	—0.185	Not sig.
a/b $(d+K)$	—0.161	Not sig.	0.113	Not sig.
a/b L_8	—0.489	—0.745 —0.107	—0.331	Not sig.
a/b BB	—0.098	Not sig.	0.037	Not sig.
a/b SS	0.784	0.902 0.557	0.558	0.789 0.199
Pt SS	0.723	0.872 0.451	0.500	0.752 0.121
a/b Cap	0.925 ($N = 18$)	0.972 0.806	0.862 ($N = 20$)	0.944 0.678
a/b Men	0.933	0.971 0.849	———	———

Meaning of symbols used:

r = correlation coefficient.

a/b = age at point of maximum rate of growth (abscissa of point of inflection).

Max = maximum absolute rate of growth (dy/dx at point of inflection).

K = length gained during adolescent growth cycle.

b = rate-constant.

$(d+K)$ = adult length (upper asymptote of curve).

L_8 = observed length at 8 years.

BB = body build index at 18 to 19 years.

SS = age of first recorded observation of secondary sex development.

Pt = first observed point on S-shaped adolescent growth curve.

Cap = age when X-ray first shows fusion of capitellum of humerus.

Men = age of menarche in the girls.

Not sig. = not significantly different from zero, by t-test for a sample of 24.

the boys may be partly due to the fact that, as already noted under sex differences, the adolescent gain, K, contributes a greater proportion of the total adult length for the boys than it contributes for the girls.

Our correlation between adult length $(d + K)$ and the rate-constant b is in the negative direction and is even weaker than the correlation between adult length and the constant K, being of only borderline significance for the boys and not significant for the girls.

We find a weak but significant negative correlation between the constant K and the constant b, showing some tendency for a greater total gain in length during the adolescent cycle to be associated with a less rapid rate of progress in completing the cycle.

Since the photographs of our boys had shown some very suggestive evidence of a relationship between the growth pattern index $100b/K$ and the general body build, we wanted to try a correlation between this index and some sort of index that would be an expression of the body build. The boys and girls of the Child Research Council series have never been classified according to Sheldon's somatotypes, so we could not use the somatotype status for correlations. We did, however, use a composite index of body build, made up from indices which were available for the boys and girls of our group. This body build index consists of the product of relative sitting height and weight-height index, divided by the shoulder-width-hip-width index. High values for this composite index correspond to a relatively short-legged, relatively heavy, and wide-hipped person; in other words, a person with a generally gynic build. Low values of the index correspond to a relatively long-legged, lean, and broad-shouldered person; in other words, a person with a generally andric body build. The 48 adolescents of our group show a significant sex difference ($t = 4.754$; P is less than 0.001) in favor of smaller values of the body build index in the boys. The correlation which we obtained between this body build index and the growth pattern index $100b/K$ was significantly positive for the 24 boys, but disappointingly weak (0.500). For our girls the correlation between the two indices is not significant.

B. Correlations involving timing of point of maximum rate of growth (*table 5*): Some of the more interesting correlations which we investigated were those which involved the timing of the point of maximum rate of growth in these boys and girls, as represented by age at the point of inflection of the Gompertz curve $(x = a/b)$.

For the relation between age at the point of maximum rate of growth

in length and the maximum rate that is attained by the individual, we find a significant negative correlation (—0.746 for the 24 girls and —0.603 for the 24 boys) showing a tendency for those who reach their maximum rate of growth at an early age to attain a more rapid maximum rate than those who reach this point at a later age. This is in general agreement with reports in the literature by Shuttleworth ('39), by Tanner ('51), and by Simmons and Greulich ('43), with respect to greater "intensity of growth" or a greater "peak velocity" for those individuals whose adolescent spurt occurs early.

For the relation between age at the point of maximum rate of growth in length and the actual magnitude of the total adolescent gain in length, as represented by the constant K, we again find a significant negative correlation (—0.725) for the girls of our group; but for our boys this negative correlation is of only borderline significance.

For neither our boys nor our girls do we find any significant correlation for age at the point of maximum rate of growth and the value of the rate-constant b. Nor do we find any correlation between age at the point of maximum rate of growth and the adult length attained by the individual, the early maturing individuals (from this standpoint) showing no tendency to be either taller or shorter as adults than the later maturing individuals.

Reports in the literature had led us to expect a significant negative correlation between age at the point of maximum rate of growth and the observed length of the individual at the age of 8 years; in other words, that the children whose length at 8 years was greater would tend to reach their adolescent spurt at an earlier age. We did obtain negative correlations, but they are disappointingly weak (—0.489 for our 24 girls and —0.331, which is not significant, for our boys).

We also had some expectation of finding a significant correlation between age at the point of maximum growth and the individual's body build index, especially in view of the report of Tanner ('51), and the findings of other authors quoted by Tanner, to the effect that early maturing individuals tend to be less linear or ectomorphic, to have relatively shorter legs and wider hips, and to be generally less andric or more gynic than the later maturing individuals. However, for neither the girls nor the boys of our group do we find any correlation whatsoever between our body build index and age at the point of maximum rate of growth.

Our best correlations are those associated with timing of point of

maximum rate of growth and timing of certain physiological events in these boys and girls. The correlation between age at point of maximum growth and age of the first recorded sign of secondary sex development is significantly positive (0.784 for the girls and 0.558 for the boys). The poorer correlation for the boys is, we believe, largely due to greater inaccuracy of our records of the *SS* age for the boys. Our correlations between first sign of secondary sex development and first observed length point on the adolescent growth curve are essentially the same as the correlations between point of maximum rate of growth and first sign of secondary sex development—again considerably better for our girls than for our boys.

Our correlations between age at point of maximum rate of growth and fusion of the capitellum of the humerus (the first long-bone epiphysis to close) are good for both the girls (0.925) and the boys (0.862).

Best of all is our correlation between age at point of maximum rate of growth and age of the girl at menarche (0.933). We would, of course, expect a significant correlation with menarcheal age, in view of the reports by Shuttleworth ('39), by Simmons and Greulich ('43), and by Tanner ('51). But we were delighted to find our own correlation as good as it is. It strengthens our faith in the validity of the calculated Gompertz curves as a description of the growth pattern of individual adolescents. (See fig. 5 for calculated regression line and observed age points for the relation between menarcheal age and age at point of maximum rate of growth, as represented by the point of inflection of the calculated Gompertz curve, for the 24 girls of our group.)

SUMMARY

The Gompertz equation $Y = d + Ke^{-e^{a-bx}}$ has been fitted to observed length during the adolescent growth cycle of 48 individual boys and girls.

The constants, asymptotes, and points of inflection of the calculated Gompertz curves give us useful tools for studying the typical pattern of growth during the adolescent cycle, for investigating individual differences and sex differences in pattern of growth, and for investigating the timing of certain physiological events in relation to the pattern of the growth cycle.

We find significant sex differences in the value of the constants K and b; in the level of the lower and upper asymptotes of the curve; in the timing of the point of maximum rate of growth, as represented by the derivative at the point of inflection of the Gompertz curve; in the

timing of both points of inflection of the first derivative curve; in the timing of certain physiological events that appear to be related to the pattern of the growth cycle; and in the body build index of these individuals.

Within each sex we find significant correlations between several of the constants and asymptotes of the curve; between the timing of the point of maximum rate of growth, as represented by the point of inflection of the Gompertz curve, and timing of physiological events such as the first sign of secondary sex development, the closure of the first long-bone epiphysis, and in girls the occurrence of the menarche; between timing of the point of maximum rate of growth and the maximum rate that is attained; and between timing of the point of maximum rate of growth and magnitude of the total gain in length during the adolescent cycle, as represented by the constant K.

We find no significant correlation between timing of the point of maximum rate of growth and the adult length attained by the individual and very little evidence of correlation between timing of the point of maximum rate of growth and length of the individual at age 8 years.

A comparison of nude photographs, at least of the boys of our group, with the growth pattern index $100b/K$ suggests a relationship between the value of this index and body build of the individual, particularly with reference to androgyny. But the actual correlation between the index $100b/K$ and our body build index for these boys at age 18 to 19 years is disappointingly weak.

We also find no correlation between our body build index and timing of the point of maximum rate of growth, though various reports in the literature led us to expect a more gynic body build in those individuals who reach their point of maximum rate of growth at an early age.

A comparison of our individual growth curves for the adolescent cycle of growth in length with the trend of the averaged annual measurements of the same group of individuals brings out the inadequacy of averaged measurements as a description of the growth of individuals during this age period.

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APPENDIX

SAMPLE CALCULATION OF GOMPERTZ CURVE AND FIRST DERIVATIVE CURVE USING COURTIS TABLE

(This is the curve shown in fig. 3.)

Observed upper asymptote $(d + K) = 156.5$ cm
Estimated lower asymptote $d = 129$ cm
Constant K $156.5 - 129 = 27.5$ cm

x AGE (MOS.)	Y OBS. LENGTH (CM)	$y = Y - 129$ CM	PERCENT $100\ y/K$	I FROM COURTIS TABLE
117	131.2	2.2	8.00	20.73
120	133.4	4.4	16.00	23.94
123	135.0	6.0	21.82	25.79
125	138.3	9.3	33.81	29.18
129	140.6	11.6	42.18	31.48
135	145.4	16.4	59.64	36.60
138	147.9	18.9	68.73	39.81
144	151.2	22.2	80.73	45.42
150	152.5	23.5	85.45	48.50
162	155.1	26.1	94.91	59.52

Calculation of straight line, $I = i + Rx$, by method of least squares:

$N = 10$

$$m_x = \frac{\Sigma x}{N} = 134.3 \qquad m_I = \frac{\Sigma I}{N} = 36.097$$

$$\sigma_x = \sqrt{\frac{\Sigma x^2}{N} - (m_x)^2} = 13.6678 \qquad \sigma_I = \sqrt{\frac{\Sigma I^2}{N} - (m_I)^2} = 11.6737$$

Sum of cross products: $\Sigma xI = 50{,}071.30$

Correlation coefficient: $$r = \frac{\frac{\Sigma xI}{N} - m_x m_I}{\sigma_x \sigma_I} = \frac{159.3029}{159.5538} = 0.998427$$

Slope of calculated line: $$R = r\frac{\sigma_I}{\sigma_x} = 0.852759$$

Intercept: $i = m_I - Rm_x = -78.43$

Calculated straight line: $I = i + Rx = -78.43 + 0.852759x$

Equivalent constants for exponential form of Gompertz curve:

$b = R/10 = 0.0852759$

$a = (30 - i)/10 = 10.843$

CALCULATION OF POINTS

x AGE (mos.)	CALC. I*	$100\,y/K$ (Courtis table)	CALC. y (cm)	CALC. $Y = y + 129$ (cm)	$(a - bx) = (30 - I)/10$	e^{a-bx} (Expon. table)	be^{a-bx} ($b = 0.0853$)	$dy/dx = ybe^{a-bx}$ (cm/mo.)
108	13.69	0.60	0.17	129.17	1.631	5.109	0.4358	0.074
114	18.81	4.69	1.29	130.29	1.119	3.065	0.2614	0.337
120	23.93	15.97	4.39	133.39	0.607	1.840	0.1570	0.689
126	29.05	33.30	9.16	138.16	0.095	1.100	0.0938	0.859
132	34.17	51.73	14.23	143.23	—0.417	0.659	0.0562	0.800
138	39.28	67.35	18.52	147.52	—0.928	0.395	0.0337	0.624
144	44.40	78.90	21.70	150.70	—1.440	0.237	0.0202	0.438
150	49.52	86.76	23.86	152.86	—1.952	0.142	0.0121	0.289
156	54.64	91.84	25.26	154.26	—2.464	0.085	0.0072	0.182
162	59.76	95.04	26.14	155.14	—2.976	0.051	0.0044	0.115
168	64.87	96.99	26.67	155.67	—3.487	0.030	0.0026	0.069
174	69.99	98.18	27.00	156.00	—3.999	0.018	0.0015	0.040
180	75.11	98.97	27.22	156.22	—4.511	0.011	0.0009	0.024
192	85.35	99.61	27.39	156.39	—5.535	0.0039	0.0003	0.008
204	95.58	99.86	27.46	156.46	—6.558	0.0015	0.0001	0.003
216	105.82	99.95	27.49	156.49	—7.582	0.0005	0.00004	0.001

Point of inflection of Gompertz curve
(Maximum point of first derivative curve):

$x = a/b = 127.15$ mos.
$y = 0.368K = 10.12$ cm.
$Y = 129 + 10.12 = 139.12$ cm.
$dy/dx = y \cdot b = 10.12\,(0.0853) = 0.863$ cm/mo.

First point of inflection of first derivative curve:

$x = a/b - 1/b\,(0.9625) = 127.15 - 11.28 = 115.87$ mos.
$dy/dx = 0.19bK = 0.446$ cm/mo.

Second point of inflection of first derivative curve:

$x = a/b + 1/b\,(0.9625) = 127.15 + 11.28 = 138.43$ mos.
$dy/dx = 0.26bK = 0.610$ cm/mo.

* The value of I, for each given value of x, is calculated from the straight line, $I = i + Rx$, by substituting the calculated values of the constants R and i.

BOOK REVIEWS

Dynamic Anthropometry. Edited by EARL W. COUNT. 203 pp. Ann. N. Y. Acad. Sci., *63*, Art. 4, 1955.

These 200 pages are the record of a two-day symposium held by the New York Academy of Sciences; they contain 16 papers of varying length and quality, attended by virtually no discussion. Most appropriately the book begins, more or less, with a charmingly oldfashioned photograph of D'Arcy Thompson and ends with a rather reflective picture entitled "close-up buttock pattern (seated)" which strongly suggests the quizzical expression of an ectoplasmic owl.

Professor Earl Count was in the chair at the symposium and he contributes an introduction which travels both wide and deep into the subject matter of human biology. I cannot honestly feel, however, that the conference as a whole has followed him, and perhaps this was due to some confusion of thought as to its purpose. One wonders to whom the proceedings are addressed; with 16 papers read in two days no contributor can hope to do more than sketch the outlines of his topic, and none of the treatments is at a level which would inform the hardened professional physical anthropologist. The best audience to recommend the book to would be that of the senior anthropology student, perhaps, particularly as the background for a seminar wherein the teacher could follow up some of the many hares started, but not pursued, in these pages.

The title, *Dynamic Anthropometry*, has a pleasantly ambiguous air: is it the men or the measurements that are in motion? After all, anthropometry itself is a craft, a mere collection of methods for measuring aspects of the human. A book, or a series such as *Methods in Medical Research*, preferably combined with tabulations of results similar to those in the *Handbook of Physiological Data*, would be extremely useful at the present juncture, provided only that the methods were described and illustrated in sufficient detail for anyone with proper training to repeat them. The methods would have to include the classical body measurements, the measurements used in kinematic anthropometry, body photography, still and moving, measurements by X-rays, measurements of skin and eye and hair color, measurements of body tissue composition by physical and chemical means, and such other physical and chemical procedures as are not readily available from other sources. Certain mathematical techniques peculiar to anthropometry or developed par-

* The value of I, for each given value of x, is calculated from the straight line, $I = i + Rx$, by substituting the calculated values of the constants R and i.

ticularly in its service should also be included. But clearly this symposium does not aim at being a handbook of anthropometric methods. At first, it seems, it is the measurements that are on the move; latterly, after p. 553, the men.

This last third is in some ways the most interesting portion of the book, in that the techniques for dealing with the quantification of movement in man are perhaps less well known than they should be. Elftman contributes a short and pithy introduction to the study of man's movement. He mentions for example, though he does not have time to go into the really interesting problems: the type of build most suited anatomically to each type of athletic task, the effect of putting on fat on patterns of movement and the ways in which people of different body builds have their action patterns preconditioned by their shape. Dempster, in the next contribution, carries further the technical discussion of plotting movements, linkage systems, and joint ranges, and touches on the possibility of studying the effect of psychological states on habitual action patterns. We have the foundation here, perhaps, of a true investigation of postural symbolism and "language"; a study which would bring the human biologist and the psychologist into even closer contact as they endeavor to pin down between them the elusive concept of the body image and its changes. Evans, in the same section, writes on the stress-coat technique for predicting the likely sites of fracture of bones, Abt introduces a peculiarly life-like and useful full-size model of a man with correct joint linkages and properly distributed weight, and Hertzberg describes with skill and humor some problems encountered in human engineering, in particular that perennial war-time problem "What happens to the buttocks when you sit on them?" Gumbril's Patent Smallclothes appear at last in practical form on page 626—no longer, alas, the "delicious pneu" but only "dynamic inflatable cushion"—indeed, they appear with complications Huxley never envisaged, but would doubtless have dealt with effectively, seeing they consist of a continuous forty-second cycle of gluteal tumescence and detumescence. But then Gumbril never had to sit in chapel for 6-10 hours at a stretch, which is Dr. Herzberg's target time.

To return, however, to the first two-thirds of the book: here the designation "dynamic" is used, I suppose, figuratively, and in the hope that the subjects dealt with constitute the growing point of physical anthropology. Rashevsky considers plant and animal form from the point of view of engineering design; Brillouin contributes an intriguing note well calculated to secure readers for books and discussions on infor-

mation and system theory as applied to living organisms; Mainland has some characteristically sensible things to say about elementary statistics; Bonin urges anthropologists to begin quantitative work on the structure of the brain. There are two papers that deal with the allometric technique of handling growth data; neither advances the subject much. Moss has the unenviable task of presenting in 8 pages data that he refers to as in the press in two complete papers. It may be this condensation which is responsible for his sweeping blandly without apparently noticing them, through all the difficulties of the allometric technique, pointed out in detail by Sholl ('54), Tanner ('51) and above all Richards and Kavanagh ('45). Dr. Richards himself contributes, at p. 490, the wisest remarks on allometry to be found here. He also contributes one of the best articles in the book; it covers, though, less thoroughly, the ground of the brilliant 1945 chapter in D'Arcy Thompson's Festschrift, and if it sends a few readers back to that fundamental paper, that is enough to justify the symposium.

Meredith contributes some very pertinent and experienced remarks about the technical precautions necessary for taking measurements suitable for use in longitudinal studies of individual children; Garn discusses the technique of so-called pattern analysis with great clarity and effectiveness—though not enough, I suspect, to convince biometricians of its usefulness when compared with more rigorous, if more exacting, multivariate techniques. Brožek has an excellent chapter on the study of body composition by physical, chemical and anthropometric techniques, in which he compares the uses of each type of approach, refreshingly refuses to be partisan, and argues for a combined attack on the problems of human shape, size and composition by means of simultaneously applied caliper measurements, X-ray measurements, somatotype pictures, and densitometric and chemical dilution methods—a program with which I am in total agreement.

Certainly this is a useful symposium at a workaday level. But *dynamic anthropometry?* Surely that must mean something more than this? Certainly new methods are mentioned, though scarcely paraded, here and some older and relatively neglected ones, like the method of transformed co-ordinates, are represented. But new techniques do not make anthropometry dynamic any more than the wide screen makes the cinema artistically fruitful. Only by the *use* of the measurements can anthropometry earn for itself the title of this volume; only by the significance of its contribution to the general biological context of the day. And in this respect it seems to me this book falls short of its title's

promise. Where are the chapters describing the contributions of heredity and environment to the genesis of adult physique, the effect of culture and subculture on the total fat, the place of physique in assortative mating in Western and Eastern cultures, the statistics describing the selection of physique by climate recently investigated by Schreider? Where are the descriptions of the mathematical techniques needed to place the data of physical anthropology once more in the forefront of genetical theory, this time through polygenic systems like those controlling stature? Where are methods of comparing the total growth curves of man and apes, man and man; for describing the effects of sickness, the secular changes, the usefulness as a sociological yardstick? I am aware this is unfair criticism; indeed, no criticism at all, since I am asking for a different symposium and a different book. I do so unrepentantly; let us praise this one as useful in so far as it goes, but not think that it goes very far. Anthropometry is a technique; let us publish a series of detailed descriptions so as to catalog our working tools; and let us separately, one day of courage, publish an account of what uses, in theory and practice, these techniques can be put to, an account of what the growing discipline of human biology has to offer in the attempt to understand man as part of nature.

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Demographic Yearbook 1955. Statistical Office of the United Nations. xi + 781 pp. United Nations, New York, 1955. $8.50 Clothbound ($7.00 Paperbound).

Investigators in the various branches of the biological sciences will find this volume, the seventh in an annual series, a rich storehouse of information on international population data and vital statistics. In addition to bringing up-to-date the usual time series on population esti-

mates, fertility, mortality, longevity, marriage and divorce, each issue of the *Demographic Yearbook* features a special topic of demographic interest. A large part of this edition is given to the population censuses taken in a large number of countries throughout the world in the decade 1945-1954, and constitutes the most comprehensive compilation of census returns ever assembled.

Recent census data for the individual countries are given in considerable detail—according to age, sex, marital status, urban-rural distribution, size of locality, size of household, literacy, and labor force. Of particular interest is table 11, which shows population figures by single years of age for each sex. But the statistics presented are not limited to those which have become available in the past decade. Table 4, for example, gives for each of 198 geographic areas the population at every census taken since 1850; for many of these areas intercensal rates of increase are shown.

The second part of the *Demographic Yearbook* is devoted to international vital statistics. The tables on natality show both the number of live births and the rates according to age of mother and order of birth. About 75 pages are taken up with mortality statistics, subdivided by age, sex, and cause of death. The most recent available data on expectation of life for 62 geographic areas are given by age, separately for males and females. Unfortunately, such data are not available for large areas of the world—China, for example—while in other areas they are dated; the latest life table for the U. S. S. R. is for the years 1926-27 and relates only to the European part.

International comparability of demographic data is often impaired because of differences from one country to another in the concepts and procedures used in collecting, recording, and tabulating population data and vital statistics. The technical notes on the statistical tables in the *Yearbook* are invaluable for evaluating the quality and comparability of such data. Another useful feature is the detailed bibliography of recent official publications containing census and other demographic statistics for each area of the world.

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Hormones and the Aging Process. Edited by EARL T. ENGLE and GREGORY PINCUS. 323 pp. Academic Press, Inc., New York, 1956.

Many of the experiences in endocrinology have been derived from studies of complete exclusion of the hormones and from the administration of excessive amounts of these agents. By contrast, the conference reported in the work under review dealt with the more subtle questions of hormonal regulation in relation to aging and chronic stress. No attempt was made to define an "aging process."

Outside of regression of the gonads in females, no aspect of aging could unequivocally be assigned to a hormonal cause. However, for sex steroids, adrenal cortical steroids, thyroid hormones, related fields of calcium and protein metabolism, and water and electrolyte regulation, a considerable body of evidence is presented which speaks for a characterization of aging by such biochemical dimensions. In many instances the regulatory nature of these endocrine changes with time and aging was explored. The process of involution of the ovaries was shown to be in the gonad itself and not in a failure of pituitary stimulation or tissue response to the sex steroids. Similarly the changing pattern of adrenal cortical steroid production is not related to a failure of production of pituitary ACTH. There appears to be a changing economy for such adrenal hormones with less "needed" and less produced. This would speak for an adequate retention of pituitary-adrenal regulation, adapting to the changing bodily status with age. Thyroid function is diminished in later adult life but tissue capacity to respond to the hormone remains. In similar fashion a variety of changing metabolic activities are related to altered hormonal and non-endocrine influences such as general activity, appetite, nutrition, etc.

The recurring question raised by each report is whether these hormonal changes are the result of or the cause of the aging phenomena. As presented, the failure of "hormonal replacement therapy" to repair more than isolated aspects of the defects of aging is in keeping with the need for more extensive understanding along such lines. The need for considering individual differences in status as opposed to chronological age, past history of chronic stresses, degree of tissue changes, associated degenerative or neoplastic diseases, etc. in extensions of the work is clearly indicated in the discussions reported. All this is in keeping with the opening remarks of the editors who present both the conven-

ing of the conference and this report " as stimulants to obviously needed investigation " in a difficult and neglected field.

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The Direction of Human Development: Biological and Social Bases. By M. F. ASHLEY MONTAGU. ix + 404 pp. New York: Harper & Bros., 1955. $5.00.

The author claims the content of this book to be " the most dramatic and important experience " of his life. The publisher refers to it as an " unprecedented assembly " of research data from biology, physiology, medicine, psychology, sociology, education, anthropology, and related fields which sets forth the " heavy weight of evidence to affirm the necessary role of cooperation and affection in the life of the individual in society." After such promise, this reviewer was badly let down!

In his Foreword the author anticipates criticism. He states that he has omitted much evidence for his various claims; he admits freely to the charge of over-simplification but believes his message sufficiently dramatic and important at the present time to warrant this attempt to demonstrate the categorical imperatives of love and of cooperation in man's social life.

Anything like an adequate critical review would examine in detail the author's use of such a tremendous volume of research literature. The author has, indeed, read widely and fruitfully; he has written boldly as he has attempted to weave together this great mass of material from more than 700 references. Such an heroic undertaking is bound to find criticism at the hands of the less courageous.

The theme of the book is an extension of an idea which Professor Montagu has advanced before—that the end to which all nature strives is social cooperation; that the basic and most powerful motive in human experience is love; that human development trends in the direction of greater cooperation and greater social cohesiveness; that man should profit from the lesson of his evolutionary heritage and aid rather than hinder this development. The author rejects out of hand the idea that human nature is morally neutral. Human beings are born good—" ' good ' in the sense that there is no evil or hostility in them, but that

at birth they are wholly prepared, equipped, to function as creatures who not only want and need to be loved by others, but who also want and need to love others." (p. 289) Herein is a reaffirmation of Rousseau and the English romantic poets of a later day. Thus the book might be viewed as a humanistic counter move to the dictation of despair which crowds our literature at the present time, finding in man a grim existential character or at least a dual nature, with the death wish as prominent as the life wish.

This reviewer is less concerned with the admitted over-simplification and the omission of additional evidence than with two other flaws:

The evidence adduced is uncritically handled. A homely antecdote from a popular magazine on child care is quoted with as much conviction and considered as significant as a carefully controlled scientific study published in a scholarly journal. For purposes of scientific evidence, the author makes no distinction among a clinical record of one case, a carefully controlled laboratory experiment, an experiential anecdote, and sheer speculation.

The evidence adduced is selected to support the main thesis. The author offers experimental evidence supporting his general thesis and omits equally adequate evidence tending to confound it. For example, he describes Levy's well known puppy experiment at some length to show that reinforcement of the sucking drive follows frustrating that drive; he omits the important work of Brodbeck and Sears, and of others, showing that sucking resembles a learned response rather than an innate drive, and is weakened, not strengthened, by disuse. The text gives much space to Ribble's discussions of the importance of early nurturing experience of infants, but pays no attention to the counter evidence and sharp criticisms which have been advanced against this point of view.

That developmental processes exhibit directionality is an insistent idea—one not easily put aside, even by the most ateleological of scientists. But writers such as Sinnott or Lillie stay fairly close to the material with which they are most familiar.

There is need for synthesis, and the man who attempts to view the scattered fragments of evidence from various fields so as to discern the pattern always hazards sharp criticism. His "theory" which fills the gaps between the known and plotted areas should, however, be subject to test. Montagu's book is a statement of a faith, not a theory. The frankly evangelical tone of the book may make it more suitable for the trade than for science.

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Proceedings of the World Population Conference, 1954, Rome, 31 August—10 September 1954. Volume I, xiii + 1040 pp. United Nations, New York, 1955. $1.50.

This is the first of six volumes of papers presented at the World Population Conference held in Rome in 1954 under the auspices of the United Nations with the close collaboration of the International Union for the Scientific Study of Population, the Food and Agriculture Organization of the United Nations, the International Bank for Reconstruction and Development, the International Labor Organization, the United Nations Educational Scientific and Cultural Organization, and the World Health Organization. This volume contains the papers presented at Meetings 2, 4, 6 and 8 which dealt with mortality and fertility trends. Meeting 2 was devoted to mortality trends with special attention to areas of lower mortality while Meeting 4 was concerned with areas of higher mortality. Meetings 6 and 8 represent a similar dichotomy in relation to fertility trends. Of the 69 papers presented at the four meetings 49 were in English, 13 in French, 5 in Spanish and 1 each in German and Chinese. Each paper is followed by a short summary in English and French. The papers have been reproduced by photo-offset from typescript.

Countries in all parts of the world and a number of international organizations are represented among the authors. Within the field covered, the papers treat a wide range of subject matter, including methodological concepts, analyses of birth and death statistics for individual countries and regions, and future projections of mortality and fertility trends. It is obviously impossible in a brief review to do justice to a compilation of this kind, but there are a few important conclusions which emerge from a general review of the various papers. In most of the areas of high mortality for which data are available a spectacular decline has occurred during the past decade. As this has not been accompanied by comparable declines in fertility, substantial population increases have resulted. In areas of low mortality there has been a further but more moderate decline. In almost all cases this has been greater for females than for males. As mortality rates of females were already lower, a widening mortality differential between the sexes has resulted.

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Structure of the Ego. By L. LANGSTROTH. 149 pp. Stanford University Press, 1955. $4.00.

The first third of the book is concerned with a description of the psychology of Otto Rank and its application to psychoanalytical treatment. It culminates in Rank's will psychology. Will and opposing will, and the earlier discussed concepts of oral sadism and libido and the social and biological self are said to explain personality and behavior. Will and opposing will are abstractions. It is through the art of interpretation "that we are able to tread a path through the mass of projections, rationalizations, and denials that go by the name of thought." (p. 34) This may be so, and it is quite possible that we do not have at present a better way of dealing with the complexities of human nature than by using crude concepts such as positive and negative identification, denial, sado-masochistic mechanisms, etc. If, however, the author speaks of forces that emanate from the nuclei in the ego structure or illustrates his psychological concepts by writing, "The will arises in the id but does not become conscious till it reaches the realm of feeling, where its content is evaluated by its feeling quality" (p. 34), the reviewer will be pardoned for not trusting Langstroth's critical abilities. Langstroth then proceeds to assign certain anatomical structures to immensely complex psychological phenomena as illustrated by the following quotations: "The will force would pass to the postcentral gyrus by the connections between the VPL nucleus and this sensory area, the opposing will or DM nucleus supplying the majority of the fibers and the conscious will or AV nucleus the minority," etc. (page 51); "If the term 'suppression' can be used to indicate a lessening of the height of contraction or a mollification of tension, then a good case can be made out for identifying the 'suppressor' bands as cortical areas where the opposing will, as represented by the DM nucleus, and the feeling content of the conscious will meet in continual interplay" (p. 85-86); "The opposing will is allocated to the DM nucleus and the feeling component of the conscious will to the suppressor band (Area 4s)" (p. 95). Modern investigators who base their conclusions on neurophysiological and psychological experiments on animals with brain lesions and on the critical evaluation of clinical cases are very hesitant to assign a precise localization to less complex functions than Langstroth discusses in this book. He adheres to a psychology that is akin to the faculty psychology of Thomas Reid (1785) and combines it with recent anatomical data

without giving a shred of evidence for the justification of such an audacious undertaking.

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The Biology of the Spirit. By EDMUND W. SINNOTT. Pp. ix + 180. New York: The Viking Press, 1955. $3.50.

Is there anything a scientist, applying the methods of science, can usefully say about the spirit, the soul, God? Is there *any* method by which he can render these intangibles tangible? This book is an answer to those questions. Writing with admirable clarity, with courage and humility, Dr. Sinnott expounds the hypotheses which, he believes, are capable of returning reasonable answers to the above questions, and also—by no means incidentally, throwing some light upon the nature of man and his relation to the universe in which he finds himself.

For many reasons the book ought to make a wide appeal to scientists. In the first place, it is relatively short; in the second place, it asks the old questions not as a dogmatist but as a scientist would ask them, and it attempts to return the answers in the light of contemporary scientific understanding; third, the book is not overburdened with the apparatus of learning; and finally, the author uses his words with caution. Hence, whether the reader will agree on all points with Dr. Sinnott or not is of no great moment—what the reader will find himself benefiting from is the experience of being fairly and squarely faced with certain elementary questions and the necessity of critically evaluating Dr. Sinnott's arguments in support of his hypotheses.

As a general rule scientists adopt a rather lazy agnostic viewpoint. The nineteenth century is generally taken to have cooked the theologian's goose and, if the latter's ghost occasionally rises to plague them, the noises it makes tend to be rather contemptuously dismissed for what they are considered to be worth. This is the materialist attitude, and that it has already done not inconsiderable harm in the world is evident. Materialists and scientific humanists will not like Dr. Sinnott's book. Unlike Huxley he believes that purpose is inherent in the very nature of life, and that it is man's job not merely to make purposes but to discover what purposes are already inbuilt in the very structure of man. The notion that man is the resultant of a long history of chance occur-

rences is only too often confused with the idea that at birth the individual is nothing but a system of random impulses out of the disorder of which culture must make a semblance of order. What is overlooked is that the system, the *organism*, at birth is already a highly organized, ordered, system, which far from requiring the imposition upon it of an externally conceived system of order, requires the nourishment and stimulation, based on an understanding of its needs, which will cause it to grow and develop so that its potentialities shall be fully and harmoniously realized. "We are standing at an impasse in our basic philosophy and seem to be faced with a choice between the physical and the spiritual side of man as the final reality," writes Dr. Sinnott, and it is out of the study of growth and development of living things that he is led to the choice of the spirit. The biological fact of self-regulation, he believes, is equatable with the psychical, and the psychical, in man, is equatable with the spirit—"the mass of natural impulse, desires, and emotions that well up out of protoplasmic purposiveness, setting up in us goals and longings of all sorts, conscious or unconscious. These are native to our living stuff, though subject to elevation or debasement."

Somatic development and psychic development, as exhibited on the one hand by the tendency among living things to reach and maintain an organized living system, and on the other by persistent directiveness or goal-seeking, Dr. Sinnott sees as fundamentally the same thing, merely two aspects of the basic regulatory character displayed by all living stuff. Conscious purpose is the inner experience of protoplasmic goal-seeking. I do not suppose that Dr. Sinnott would deny that with the addition of culture that purpose becomes or is capable of becoming much more. The purposes of ameba and man spring from the same fundamental unity of protoplasmic stuff, at the functional level expressing themselves as the integrals of different levels of integration. Man is not merely a rational being but fundamentally a seeking, desiring, aspiring one. "From this comes the force that moves and guides him" and "gives hope of making our social order a far better one than it now is." "He who learns to remold the heart's desire, and not the mind's intent alone, will hold in his hands the key to our salvation."

In brief, what Dr. Sinnott is saying is that it is through science that we are learning that science is not enough, or as Pascal put it, the heart has its reasons of which the reason knows not. Some scientists, in the contemporary period, have for the first time in the history of science been inquiring into the heart's reasons, and they have come up with some astonishing findings. I am sure that Dr. Sinnott is familiar with

much of this work, although he makes no direct reference to it, for it supports some of his arguments up to the hilt. "Love," concludes Dr. Sinnott, "is the climax of all goal-seeking, protoplasm's final consummation."

The system of goals and biological purposes which the organism constitutes would suggest the existence of a Principle of Organization—a principle which brings order out of randomness, spirit out of matter and personality out of neutral and impersonal stuff—thus providing the three great essentials for religion. The Principle of Organization lifted above its expression in matter into the realm of spirit, Dr. Sinnott believes, may be thought of as an attribute of God. "God . . . is that Power which creates organized living systems and sets up in them the goals toward which they move and culminate in the aspirations of the spirit."

This may sound like the old stand again, and in a very real sense it is, except that Dr. Sinnott speaks as a scientist, not as a dogmatist or authoritarian, but as a humble man thinking aloud as rigorously, as honestly, and as helpfully as he can. This is the contribution which he makes in this book. It will be read with the respect and gratitude that it deserves.

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BOOK NOTICES

NEUROPHARMACOLOGY. Edited by Harold A. Abramson. 210 pp. (1st conference), 328 pp. (2nd conference). The Josiah Macy, Jr. Foundation, New York, 1955, 1956. $4.25 each. The first conference was devoted to such topics as brain circulation and metabolism, functional organization of the brain, and electrical activity in relation to anesthesia. The second conference dealt more directly with "chemopsychology," defined as the study of the influence of chemical substances upon human behavior. Special attention was given to the effects of lysergic acid diethylamide.

SCIENCE IN PROGRESS. Edited by George A. Baitsell. xviii + 343 pp. Yale University Press, New Haven, 1955. $6.50. The current volume, ninth in the series established in 1939, contains papers by 10 outstanding scientists, presented in the framework of Sigma Xi National Lectureships. Particularly relevant are the contribution on human heredity by L. H. Snyder and George Wald's lecture on the molecular basis of visual excitation.

ALLGEMEINE THEORIE DER MENSCHLICHEN HALTUNG UND BEWEGUNG. By F. J. J. Buytendijk. 367 pp. Springer, Berlin, 1956. DM 40.0. In this comprehensive monograph a general theory of human posture and movement is offered as a combination of the physiological and psychological approach to the problem.

A STUDY OF THINKING. By J. S. Bruner, J. J. Goodnow, and G. A. Austin. xi + 330 pp. John Wiley, New York, 1956. $5.50. Records the outcome of a 5-year program of research on cognition carried on in the Laboratory of Social Relations at Harvard University and focussed on the phenomena of categorizing (conceptualizing). R. W. Brown contributed an appendix on applications to psycholinguistics.

LES MÉCANISMES CÉRÉBRAUX DE LA PRISE DE CONSCIENCE. By Paul Chauchard. 240 pp. Masson, Paris, 1956. Frs. 1,300. *Cerebral Mechanisms of Awareness* attempts to synthetize the contributions of 3 "schools" of neurophysiology: French (L. Lapicque), Russian (I. P. Pavlov), and English (C. Sherrington). The three parts deal with sleep, "neuro-consciousness," and implications for pathology.

TOWN AND COUNTRY IN BRAZIL. By Marvin Harris. x + 302 pp. Columbia University Press, New York, 1956. $4.50. Description of a small county seat in the mountainous region of eastern Brazil from the point of view of social anthropology.

IMMIGRANTS AND THEIR CHILDREN, 1850-1950. By E. P. Hutchinson. xiv + 391 pp. John Wiley, New York, 1956. $6.50. A volume in the Census Monograph Series, the book gathers information on the composition, geographical distribution and occupational stratification of U. S. population of

foreign stock over the last 100 years, with emphasis on the changes since 1920.

NEBRASKA SYMPOSIUM ON MOTIVATION, 1956. Edited by Marshall R. Jones. viii + 311 pp. University of Nebraska Press, Lincoln, 1956. $3.00 paper, $3.50 cloth. Text and detailed discussions of 6 papers, covering a wide range of topics in the study of motivation (incl. "sex drive" and a neurological approach to motivation), originally presented at the 4th symposium on Current Theory and Research in Motivation, financed through a grant from the U. S. Public Health Service.

RESERPINE IN THE TREATMENT OF NEUROPSYCHIATRIC, NEUROLOGICAL AND RELATED CLINICAL PROBLEMS. Edited by F. F. Yonkman. Annals of the New York Academy of Sciences, Vol. 61, Art. 1, 280 pp., New York, 1955. $3.50. In addition to the therapeutic applications in a variety of situations, the volume enhances our understanding of the scope and nature of action of this important tranquilizing drug.

LA POBLACIÓN DE VERACRUZ. By Felipe Montemayor. 78 pp. Gobierno de Veracruz, 1950-1956. Following a brief survey of languages and population groups, the author presents the physical characteristics largely on the basis of Johanna Faulhaber's *La Antropología Física de Veracruz* (2 vols., 1950-1956).

BIOGRAPHICAL MEMOIRS. National Academy of Sciences. 359 pp. Columbia University Press, New York, 1956. $5.00. Of special interest are the biographies of two outstanding pioneers of scientific psychology, Raymond Dodge, the student of visual motor functions and of the *Conditions and Consequences of Human Variability* (Yale University Press, 1931), and Carl Emil Seashore who spent 50 years *On Search of Beauty in Music* (Ronald Press, 1947, with a fitting subtitle: *A Scientific Approach to Musical Esthetics*).

PEACEFUL USES OF ATOMIC ENERGY. Vol. 10, 11, 16, Proceedings of the International Conference in Geneva, August, 1955. 544, 402, 203 pp. United Nations, New York, 1956. $8., $8., $5. This important conference set several records, including the speed with which the materials are being made available. The history of the conference and the special evening lectures are presented in Vol. 16. Biological effects of radiation are considered in Vol. 10 and 11, including modes of radiation injury and effects on bones and reproductive system, protection and recovery, genetic effects, use of isotopes and nuclear radiations in the diagnosis and study of disease and in therapy.

BIOMETRIKA TABLES FOR STATISTICIANS. Edited by E. S. Pearson and H. O. Hartley. xiv + 238 pp. Cambridge University Press, New York, 1956. $4.50. Publication of this volume 42 years after the issue of Karl Pearson's *Tables for Statisticians and Biometricians* indicates a continuing need for devices which would "reduce the labour of statistical arithmetic." The present volume contains the more commonly used tables and will be

followed by a second volume with more specialized tabular materials. There is a large introduction (100 pp.)

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE KNEE. By S. I. Pyle and N. L. Hoerr. viii + 82 pp. Charles C. Thomas, Springfield, 1955. $4.25. The first in the new series of radiographic standards of skeletal maturation, based on the Brush Foundation study, was published in 1950 (hand and wrist, by W. E. Greulich and S. Idell Pyle, Stanford University Press). In the second atlas the authors briefly describe the concept of skeletal age, define the anatomic and radiographic terms, and present 29 plates together with discussion of maturity indicators and developmental features for ages from birth to 18 years. An important standard of reference.

POLICE DRUGS. By Jean Rolin. Translated by L. J. Bendit. x + 194 pp. Philosophical Library, New York, 1956. $4.75. Pharmacology (and electrophysiology) hold keys to Pandora's box containing new techniques of "brain-washing." The author, fearful of the easy misuse of the "satanic pharmacopeia," condemns narco-analysis as a technique for interrogation and forcing confession.

ON THE NATURE OF MAN. By Dagobert D. Runes. 105 pp. Philosophical Library, New York, 1956. $3.00. A collection of philosophical essays and brief "evening thoughts" reflecting the author's belief that "in reading, sometimes less is more."

STATISTICAL METHODS. By George W. Snedecor. xii + 534 pp. Iowa State College Press, Ames, Iowa, 1956. $7.50. A time-tested guide (1st ed., 1937) for uses of statistics in biology. A chapter on sampling was contributed by W. G. Cochran.

HUMAN HEREDITY HANDBOOK. By Amram Scheinfeld. 276 pp. J. B. Lippincott, Philadelphia, 1956. $3.95. Written in a breezy style, the volume represents a useful guide to the subject of human inheritance, including medical considerations.

CLASSICS OF BIOLOGY. By August Pi Suñer. Translated by Charles M. Stern. x + 337 pp. Philosophical Library, New York, 1956. A survey of the major topics of theoretical biology, documented with extracts from the writings of authors from Plato and Aristotle to Erwin Schrödinger and Ludwig von Bertalanffy.

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